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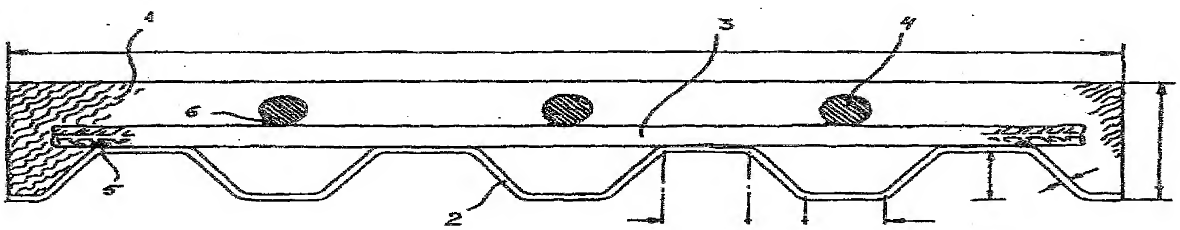

(57) Abstract

The invention relates to a hybrid article which consists of a combination of a composite material and a sheet. The hybrid article is intended for combining technical physical benefits of the composite materials and of the profiled sheet elements by establishing an intimate contact between the composite material and the sheet element. The composite material is based on cement and the sheet element is based on metal but can also be based on ceramics or plastic. The composite material contains preferably particles in the form of rocks or metals for increasing the hardness of the composite material and contains preferably also elements in the form of bars, threads, networks or fibres for establishing a reinforcement of the composite material. The sheet element is provided with a profiling, preferably having a trapezoidal cross section, for establishing an increase of the rigidity of the sheet element and for establishing an improved contact between the composite material and the sheet element.

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HYBRID PLATE AND METHOD FOR PRODUCING SUCH HYBRID PLATE

Background of the invention and description of the drawings.

The invention relates to hybrid articles composed of particle-based composite materials in intimate contact with profiled sheets preferably placed external to the bodies formed of the composite materials, as well as objects constructed from such hybrid articles.

The composite materials can be cement-based - having a certain similarity to concrete - and the profiled sheets can be of metal, e.g. steel. According to the well known art articles - typically slabs - have been composed of conventional concrete in contact with profiled steel sheets - thus, articles having an apparent resemblance with the hybrid articles of the present invention.

The hybrid articles according to the present invention are distinguished from the above articles by a completely different and superior intimate co-operation between the composite materials and the profiled sheets.

This results - as illustrated i.a. in example 1 of this description - in hybrid slabs which are stronger than corresponding conventional ones and which in addition are extremely tough as well as capable of absorbing very high concentrated loadings. This is a behaviour which is surprising to the man skilled in the art because metal sheet/concrete/hybrid articles conventionally are notorious crack-sensible/fragile and unsuitable for the absorption of more concentrated loadings.

This new - and to the man skilled in art exceedingly surprising behaviour - is obtained with a unique combination of individual per se external properties imparted to the composite materials, viz.:

a) Compressive strength of 2-10 times higher than usual concrete - typically from 80 to 300 MPa compared to conventionally 20-50 MPa.

b) Rigidity/modulus of elasticity of 1.5 - 3 times higher than for usual concrete, and

c) Toughness/energy of rupture of 5 - more than 200 times higher than that for usual concrete, and with regard to the sheets,

d) Use of profiled sheets - typically made of a strong material like steel.

In the following the mechanical action of the hybrid articles will be considered, and in this connection comparisons wil be made with prior art articles having profiled steel sheets in contact with conventional concrete, resembling the articles according to the invention.

Concrete has low tensile strength. In order to utilise concrete in bearing constructions, e.g. in slabs and beams, the concrete is tensile reinforced - conventionally with steel bars well embedded in the concrete. Usually the bars are round with profiled surfaces. They are placed well into the concrete - typically at least 1 - 1.5 times their diameter as from the surface of the concrete - and sufficiently spaced from each others so that each reinforcement steel is maintained independent in a closed body of concrete.

Considering bending affected articles - beams, slabs, etc., localisation of the steel reinforcement in form of thin sheets on the external surface of the articles instead of bar reinforcement placed farther into the concrete would be preferable as seen from a pure force balance point of view - disregarding any shear co-operation between the reinforcement and the concrete. With e.g. a 20-30% longer moment arm the carrying capacity in pure bending would be 20-30% higher.

In order to function effectively the reinforcement should, however, be placed in the concrete in such a manner that shear forces of reasonable magnitude can be transmitted between the concrete and the reinforcement. This is why reinforced concrete having profiled bars embedded deeply into the concrete well spaced apart from each others has the form it has and that articles having external sheets rarely are used, neither when the sheets are profiled.

Before considering the shear capacity itself, a short account is made for the effect of shear capacity or lack of the same - for the behaviour of reinforced concrete - exemplified by the behaviour of reinforced beams/slabs loaded by two single forces, vide Fig. 1 showing the arrangement, 2 and 3 showing sections of the slab/beam - viz. the middle section and the outer section, respectively, - the forces acting on the respective bodies being indicated with arrows.

The central section is only affected by moment - transmission of forces (compression in the upper side of the concrete and traction in the longitudinal reinforcement) does not itself require shear-connection between the reinforcement and the concrete. Failure/insufficient shear capacity has, however, important secondary effects, i.a. concerning control of crevices, vide Fig. 2.

Fig. 2 shows a segment of conventionally reinforced concrete slabs subjected to pure moment action and having good shear resistance between the reinforcement and the concrete in 1, but with poor shear resistance in 2 with good sound reinforcement 3 in the form of profiled rods a desired behaviour with formation of many very fine crevices is secured. With reinforcement in the form of profiled sheets 4 the shear resistance in constructions according to the prior art is poor resulting in development of a few very broad and deep crevices.

Beyond the moment action the outer sections are also subjected to shear actions. Thus, forces are to be transmitted from the compression zone to the reinforcement, the tension of which is reduced thereby. Without capability to transmit shear forces shear failure will occur bringing about collapse (with loadings higher than what the non-reinforced concrete plus the thin sheet can carry alone without composite co-action which usually only is a small fraction of what they can carry when fuctioning as composite article).

Fig. 3 shows a part of a slab or beam reinforced at the bottom which breaks due to shear failure between the concrete and the reinforcement.

Fig. 3 shows the behaviour of the outer section in three stages: 1, 2 and 3. The slab, which is supported at the edge 4, is stressed by the force 5. In stages 1 a tension fissure 6 is just formed in the concrete. This opens more and more because the force transmission zone C increases to the maximum size - stage 2. The zone moves out towards the support resulting finally in failure as illustrated in 3.

It is known/acknowledged that good shear resistance between concrete and steel reinforcement requires:

1) good embedment of the steel reinforcement well spaced from the surface and from each others so that the concrete mechanical squeezes about the reinforcement during shear,

2) preferably cylindrical reinforcement rods, which i.a. are optimum with regard to the above squeeze effect, and

3) preferably reinforcement rods provided with crests arranged with short mutual distances perpendicular to the longitudinal direction, cf. conventional cam steel and tentor steel.

It is - in accordance with what is said above - clearly recognised that the same degree of co-operation cannot naturally be obtained with sheets as with cylindrical shaped reinforcement rods, in particular not with sheets placed on the outer surface of the concrete articles.

Within the prior art it is known to use profiled thin sheet/concrete composite articles wherein improvements have been obtained as compared to corresponding plane sheet composites. For example it is known to use such profile sheet/concrete composites as cover elements and for a more or less degree to allow for the utilisation of the reinforcement effect of the sheets in the same manner as with steel reinforcement in ferro-concrete.

However, it is also clearly recognised that one cannot reach at all correspondingly effective co-operation between sheets and concrete as between reinforcement rods and concrete in conventional ferro-concrete. Reasonably effective utilisation of profile sheets as reinforcement is limited to constructions subjected to moderate loadings and substantially pure bending affected constructions subjected to utmost modest shear stresses.

Thus, the British Standard "Structural use of Steelwork in building BS 5950 Port 4; 1982" describes in the paragraph concerning rules for use of "profiled steel sheets" acting as composite structures together with concrete:

4.5. Requirements for composite action.
4.5.1. General. For composite action the profiled steel sheet should be capable of transmitting horizontal shear at the interface between the sheet and the concrete. This may be achieved by one or more of the methods given in 4.5.3 to 4.5.7.
4.5.2 Plain open profiled sheets. Plain open profiled sheets, as illustrated in Fig. 2 (a) and (b), are not permitted where composite action is required, unless accompanied by some means of shear connection.

Fig. 2(a) refers to slabs having trapezoidal form (much resembling the form of the sheet in example 1 of this specification). The profile shown in Fig. 2(b) is as in (a), but the sheet parts therein between the trapeziums are not plane but given a further "mini" trapezoidal profile.

With reference to the hybrid slabs according to the present invention shown in example 1 (having high apparent similarity with the above hybrid slabs (a)) this means that with such embodiment one should expect very poor behaviour, in particular under concentrated loadings with high shear stresses. This also means that according to the above requirement 4.5.2 of BS 5950 it is not allowed to use constructions "where composite action is required".

Therefore, it is to be considered very surprising for the man skilled in the art that the slab in example 1 showed high carrying capacity, including high shear resistance and very high toughness under extremely high loadings, including concentrated shear stresses.

Before explaining the invention it is, however, necessary for the understanding to consider the mechanisms involved in material failure in particle-based materials.

Rupture - failure near interfaces.

Rupture in materials like concrete near surfaces of strong materials like steel occur in the form of tension separation and separation by shear.

Usually the resistance against separation rupture between metal sheets and concrete under tension is small, in particular if it happens by careening after crack initiation. The resistance is essentially higher in pure shear. This is the main cause for the embodiment of the present invention in the form of profiled sheets as opposed to plane sheets. Hereby undesired careening failure is strongly counteracted so that contact failure through shear becomes the more dominant rupture form. In this respect the invention does not differ from the prior art constructions, e.g. the trapezoidal profile sheets of steel and conventional concrete.

On the above background it is therefore most important to consider what happens at failure caused by shear and, in the light hereof, later to consider the means provided with the present invention as compared to the prior art just for improvement of the resistance against shear failure and what is obtained by this.

Shear failure between particle based composite materials and "reinforcement" rods or profiled sheets is very complex. On a macro scale the failure can occur mainly near the metal surface (Fig. 4.1) or mainly in the composite material (Fig. 4.2).

The concrete in the surface 3 is displaced in the direction of the arrow in relation to the profiled sheet 4. In 2 the lowest part of the concrete 5 is maintained in position in relation to the profiled sheet, since failure has occurred in the concrete article as illustrated with the rupture surface 6.

Local interface failure.

Failure near the interfaces can occur by atomic separation between the atoms in the metal surface and the atoms of the composite material, but will in conventional systems also - and very likely predominantly - occur due to failure in the composite material near the interface and not in the interface itself.

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Let us consider the structure of conventional concrete adjacent a surface, e.g. a surface of a steel plate, cf. Fig. 5. The interfaces referring to concrete 1, mortar 2 and cement paste 3 are here shown; 4 is the metal plate, 1 is concrete with stones 5 and mortar 2 which in turn is composed of sand particles 6 and cement paste 3. The cement paste is composed of partly hydrated cement particles 7 forming porous hydration products 8.

Adjacent the surface the particles are less dense packed than farther away form the surface which in turn is reflected in border zones having properties deviating from the properties far into the material at good distance from the surface. This is illustrated with the curves wherein the abscissa indicates the distance from the surface of the plate and the ordinate (y) indicates the property (e.g. strength, hardness or density).

Thus, quite proximate to the steel surface there is a border zone (GZc) about 10 μm thick of cement paste wherein the material is made up of a particle structure having a lower concentration of cement particles than within the material. This zone is more porous and far weaker than the cement paste within the material.

In the exemplified concrete there is correspondingly an about 1 mm thick porous zone of mortar (GZm) having substantially higher content of cement paste and correspondingly lower content of sand particles. With strong, rigid sand particles the border zone having a low content of particles will be weaker than the mortar within the material farther away from the surface. Correspondingly there is an about 10 mm thick mortar rich zone having a low concentration of stones. This means in turn that said zone is weaker than the material farther away from the surface if the stones are stronger than the mortar.

The shear resistance can be improved in different ways by different strategies:
1) by improving the structure of the concrete, including in particular the structures of the border layers so that the strength imparting properties are improved,
2) by adapting/shaping the contours of the metal surfaces proximate the border zones so that the effect of weak border zones is reduced.

In conventional ferro-concrete strategy 2 is used in connection with steel reinforcement which is provided with about 1 mm crests. This secures that shear rupture along the reinforcement does not occur exclusively in the 10 μm thin weak border layer between the cement paste and the steel surface but also is forced to take place extensively out in the mortar/concrete.

With profiled sheets on which no particular anchoring means have been provided there are far smoother surface than with reinforcement rods and correspondingly greater problems with the fine/weak border zones.

By the approaches according to the present invention the composite materials are improved very pronounced so that it is possible to utilise conventional profiled steel sheets, which normally would be described as being smooth, in hybrid constructions together with and in intimate contact with "concrete", showing an extremely high carrying capacity, high toughness and capability to absorb extremely high shear stresses.

With reference to the complex of problems described above and by way of example composite materials with binding agents based on cement, partly conventional concrete, partly often preferred composite materials in articles according to the present invention (vide Fig. 6) are considered. The Figure shows an arrangement of binding agents proximate a boundary 1, partly conventional cement paste (Fig. 6b), partly binding agents as shown in Fig. 6a, typically used by the invention, with cement particles 2 packed essentially denser than conventionally and with additional 10-25% ultrafine SiO_3 particles deposited in the interspaces between the cement particles.

Hereby is obtained:
1) A general material improvement, e.g. typically a 5-fold increase of the strength.
2) A particular improvement of the originally porous, weak about 10 μm thick border zone; in the example a 25-fold increase of the strength. This typically brihgt about in practise:

3) As good as 100% elimination of the conventional weak border zones apart from perhaps an ultrafine zone of a thickness as a microsilica particle (an order of 100 nm = 0.1 μm).

This is reflected in a requirement to the tensile strength of the cement-based composite materials to be at least 80 MPa, preferably at least 100 MPa, more preferably at least 150 MPa, yet more preferred at least 200 MPa, most preferred at least 250 MPa, and also in the requirements to the composition of such cement-based binding agents.

Articles characterised by the binding agents of the composite materials are based on cement like Portland cement and/or Aluminate cement and preferably also ultrafine particles as microsilicate in parts by volume of 1-40%, preferably 5-25% characterised by a high total content of fine particles (e.g. cement + microsilica) of at least 50%, preferably at least 55%, more preferably at least 60%, yet more preferred of at least 65%, most preferred of at least 70% by volume of the total volume of the binding agent.

These measures lead/contribute to the fact that by the performance of the invention in practise conventional "smooth" sheets can be used obtaining the benefits of micro roughness with deviations from the plane of from 10 μm to 5 or 1 μm. Such roughness is completely insufficient to prevent rupture through the weak (about 10 μm thick) border zones between the sheets and conventional cement paste/concrete.

As it appears from the introduction of this description this approach is only part of the total structure package/property package which is characteristic for the composite materials of the present invention. In the following the problems concerning toughness/fragility will be considered.

Shear rupture (generally).

Fig. 7 illustrates the behaviour of objects - block 1 and substratum 2 - hold together by a glue joint under shear until the joint fails. Glue joints are composed of materials having a substantially linear elastic behaviour up to a maximum of stress, a behaviour

which is typical for concrete and many composite materials used in connection with the present invention. The figure shows the relationship between the shear stress and the displacement.

If two infinitely rigid bodies 1 and 2 hold together by a glue joint, which e.g. may be stretched 1 mm before total failure, are moved relative to each other the maximum tension (To) is effective all over the contact surface in the state of rupture. If on the other hand a resilient rubber carpet/conveyor belt glued to the same substrate with the same joint material as above is pulled 5 m the force will only be transmitted to a small active zone of may be only 10-20 mm in extension (depending on the thickness and rigidity 9 of the rubber belt). By further movement the contact zone fails at the edge where the force acts. The fissure propagates in that the small active contact zone is displaced inwardly.

The force being transmitted does not correspond to the total area but only to a small fraction corresponding to the extent/area of the size of the active zone. If the active zone is e.g. 20 mm and the "sheet" is 5 m, then the maximum shear force is only about 4 0/00 of the corresponding force on condition that the 5 m large sheet was infinitely rigid.

Recognition of this mechanism at contact rupture/yielding is very important for the understanding of the mode of action and the weakness of profile sheets/concrete composite articles according to the prior art and for understanding the means/measures which are made according to the present patent, which provide great, pronounced and for the man skilled in the art very surprising improvements as compared to the prior art.

It is in particular measures for securing against the above fragile behaviour in connection with strongly localised force transmission which are essential in connection with composition of the composite materials for the articles according to the present invention.

Fig. 8 shows the tensile behaviour of typical, conventional concrete 1, strong concrete 2, and 3 the same strong material as 2 imparted rupture-toughness with fibres. The relationship between tensile stress and deformation of the crackzone (RZ) is shown. The areas below the curves, which represent the work for forming a crack of unit area, are designated the respective energies of rupture G (unit N/m or N/mm).
The both very strong and very tough material represents a typical composite material according to the present invention.

What is done - beyond imparting the materials strength and rigidity - is also to impart them very high rupture-toughness/crack-toughness so that the forces can be active simultaneously over large contact areas. The concept is illustrated in Fig. 8.

While conventional concrete of moderate tensile strength (e.g. 3 N/mm^2) has moderate crack zone deformations (30-50 μm), conventional very strong concrete (having tensile strength of e.g. 10 N/mm^2) has substantially less crack zone deformations - typically about 10 μm. This manifests itself in an essentially higher fragility. Numerically this is also reflected in that the energy of rupture G (the areas below the curves) is not increased correspondingly as the strength, but roughly estimated remains unchanged. The energy of rupture for conventional concrete is of the order 100 N/m.

The composite materials used in connection with the present invention are imparted very high rupture-toughness which is expressed in terms of that they are imparted high energy of rupture of at least 500 N/m, preferably of at least 1000 N/m, more preferably of at least 2500 N/m, yet more preferred of at least 5000 N/m, still yet more preferred of at least 10,000 N/m, most preferred of at least 20,000 N/m.

Thus, there is an increase of the rupture-toughness expressed in terms of energy of rupture corresponding to from above 5 to above 200 times higher energy of rupture than for conventional concrete, including conventional very strong concretes.

The fact that the energies of rupture are increased very pronounced means also that the capability of the materials to undergo large crack zone deformations is increased cor-

respondingly (cf. Fig. 8). With reference to the previously cited/required energies of rupture (of at least 0.5 N/mm to at least 20 N/mm) the increases of the crack zone deformations are typical from 10 μm for very strong conventional concrete to above 1000 μm for the (still stronger) tough composite materials of the present invention.

The impart of the high toughness is primarily effected by incorporating fine, strong, rigid fibres, preferably in high concentrations by volume, characterised in that the particle based composite materials contain elongated particles as discrete fibres in concentrations by volume of 0.1 - 1%, and/or 1-2%, and/or 2-5%, and/or 5-10%, and/or 10-20%, and/or 20-60%.

High toughness alone, e.g. obtained with conventional, relatively weak porous concrete or mortar admix with many fibres, is not satisfactory for securing the intimate co-operation with the profiled sheets which is a characteristic for the articles according to the invention. Thus, shear failure between the concrete and the profile sheets will typically occur in the weak porous border zones (cf. Fig. 5 and the description of "border zone failure") and not within the material where the fibres act.

By making the border zones much stronger, denser and more rigid in accordance with the invention, breaks are forced to propagate to a large extent within the material (away from the metal surface) where the fibres are active and hereby securing utilisation of the essential rupture-toughness obtained with the fibres.

This again emphasises the essential combination of the invention with respect to the composite materials of a) high strength, b) high rigidity, and c) high rupture-toughness.

Comparison of the invention with constructions based on strong, rigid and tough composite materials.

It is known to produce dense particle-based composite materials having high concentrations of particles, including composite materials comprising binding agents with closely packed cement and microsilica, cf. Bache H.H., European Patent Specification

No. 0010777 "Shaped Article and Composite Material and Method for producing same".

It is also known to produce such materials having particularly high strength and rigidity obtained with very rigid, strong particles like sand and stone of Al_2O_3-containing materials, cf. Bache H.H., "Densified Cement/Ultrafine Particle-Based Materials, presented at the Second International Conference on Superplasticizer Concrete, June 1981, Ottawa, Canada. CBL Report No. 40, Aalborg Por 33 pp.

It is also known to impart rupture-toughness to such strong, rigid composite materials by incorporating fine, strong fibres, cf. Bache H.H., International Patent Application No. PCT/DK87/00072, "Compact Reinforced Composite".

From the same publication it also appears that it is known to use such material in reinforced articles - reinforced with bars, wires or network embedded in and completely enclosed by "the concrete" - in accordance with the same principles as used in connection with steel reinforcement embedded within the concrete in conventional ferro-concrete.

In the light of the technology with strong, rigid, tough composite materials, cf. the above publications, it is, however, novel and surprising to produce articles according to the present invention with sheets in intimate contact with such strong, rigid, rupture-tough composite materials.

Thus, the teaching which can be deduced from the PCT/DK87/00072 publication is quite clearly to secure reinforcement with round bars and wires firmly wedged by embedding within the "concrete". All reinforcing components are bars, wires having a substantially circular cross-section. It is mentioned in the publication that the "reinforcement" also includes U-steel and I-steel. Here the question is clearly about bars and not sheets. The question is also quite clearly about embedded reinforcement bars well enveloped by concrete and not about profile sheets placed preferably exter-

nal to the bodies formed by the composite materials as in accordance with the present invention.

There is nothing in the prior art, nor in the above mentioned publications, which in any way would lead the man skilled in the art to the present invention as to profiled sheets placed on the outside. On the contrary all teaching concerning reinforcement functions contained in the PCT/DK87/00072 publication supports the importance of total embedment.

Therefore, it must be concluded that the invention is novel and very surprising to the man skilled in the art also on the background of the above publications since these clearly will lead the man skilled in the art in a direction away from the thoughts/ideas which might lead to the invention and in no way towards the invention.

Quantization of shear behaviour (summary).

Under "calculation examples" there is shown analyses of behaviour at displacement of steel sheets fixed to large articles/bodies of composite materials. Systems, which are strongly simplified but which give a good qualitative - partly quantitative survey over what really happens, have been considered.

In the first two calculation examples input data are used, representing prior art hybrid constructions with steel sheets in contact with conventional concrete having similarity with materials and constructions used as calculation example in Steel Designers Manual.

In the last two calculation examples (3 and 4) input data are used, representing composite materials used for the present invention having similarity with the materials used in example 1 of this paper.

It is demonstrated/explained in/by the calculation examples why profile sheet/concrete articles according to the prior art function purely at displacement with pronounced

fragile behaviour (quite in accordance with British Standard's directions of not to use such constructions where "composite action" is required).

Quite in accordance with experiences of practise it is also demonstrated/explained why no benefit is obtained with a) concrete having higher strength, b) steel having higher strength. It is also demonstrated and explained why even definite negative effects of such measures - minor carrying capability, higher fragility, etc. - are incurred.

Then follows examples representing the invention. It is demonstrated/explained (cf. the calculation examples 3 and 4) why a completely different intimate co-operation between the profiled steel sheets and the composite materials, as composed within the present invention, is obtained.

Thus, surprising to the man skilled in the art it is shown that the shear capacity is increased with a factor of about 30 as compared to the behaviour for conventional concrete and also with the same factor (30) compared to conventional very strong concrete (having the same strength as the materials according to the invention but without the quite essential incorporation of high rupture-toughness according to the invention).

The results demonstrated in the calculation examples are in good harmony with reality as represented for prior art articles by the calculation examples shown in "Steel Designers Manual" and for articles of the invention by the physical tested articles described in example 1.

It is novel and surprising to the man skilled in the art to improve the shear capacity between profiled steel sheets and particle-based composite materials by imparting increased rupture-toughness to the composite materials (the concrete).

For the man skilled in the art it is yet more surprising to establish such improvements in systems by use of very strong concrete which notoriously according to known/acknowledged technique has substantially the same or lower shear capacity and higher fragility.

To the man skilled in the art it is still yet more surprising that it is now possible with the material measures according the present invention to effectively utilise plate elements of extremely high quality (strength). With the prior art the use of profiled steel sheets having much higher strength than conventionally but with halved thickness would e.g. result in marked reduction of the shear capacity and increase of the beforehand high fragility - a phenomenon which is known/acknowledged and is part of accepted design rules for such composites (cf. "Steel Designers Manual").

Composite articles according to the invention based on less rigid binding agents, e.g. plastic.

A particular aspect of the invention concerns articles wherein the composite materials are based on binding agents of less rigid/frequently very deformable materials such as e.g. binding agents of plastic materials.

As thin "glue joints" such materials are very often very suitable to hold together strong rigid components and transmit forces therebetween. Acting along similar principles the materials are also very suitable as matrix material in fine fibre composites for maintaining fine, strong, rigid fibres and transmitting forces between these. Here in particular the adhesiveness of the glue materials and their high deformability performance are utilised. Soft materials like the most types of plastic are, however, not suitable/inappropriate as materials for large components which have to be incorporated as integrated components together with e.g. steel sheets in strong and rigid hybrid constructions. Here conventional plastic materials are much too yielding.

Thus, a hypothetical hybrid construction with profiled steel sheet would, as shown in example 1, but wherein the composite material has been replaced with conventional plastic material not at all show anything like the strength and rigidity which is demonstrated with the hybrid construction in example 1 of this description.

In plastic particle based composite materials in articles/constructions according to the present invention there is provided the same properties/combinations of properties which make the composite materials appropriate for forming strong, hard, rigid and

simultaneously tough bodies with intimate mechanical co-operation with strong sheets, e.g. strong steel sheets. This is obtained with the structure composition described below.

Structure composition - particles - fibres - hybrid articles.

1. The composite materials are composed of binding agents - as for example binding agents of plastic materials wherein strong, rigid particles are incorporated - suitably in a very high concentration by volume.

In one group of interest of such particle-based composite materials for articles according to the invention very fine particles of e.g. from 50 μm and down to 0.1 μm and even 0.01 μm are used. Here the designation "cement fineness" is often used (referring to cement grains having typically an average grain size of between 5 and 15 μm, suitably with 5-10% greater than 50 μm) and "finer than cement" (e.g. referring to conventional micro silica which has a mean particle size of about 0.1 - 0.2 μm). Such materials are used in articles characterised in that the binding agents of the composite materials are based on "fine" particles of cement size - and preferable also ultrafine particles like micro silica in parts by volume of 1-40%, preferably 5-25% - characterised by a total high content of fine particles (e.g. cement + micro silica) of at least 50%, preferably at least 55%, more preferably 60%, yet more preferred of at least 65%, most preferred of at least 70% by volume based on the total volume of the binding agent.

Another group of interest of particle-based composite materials for articles according to the invention contains larger particles in high concentration by volume and no or only a small proportion of fine particles. With "larger" means larger than cement particles, typically particle sizes greater than 100 μm, however, rarely with particles substantially greater than 10 mm.

Such interesting composite materials are characterised in that the composite materials contain rigid, strong particles like particles of natural strong rocks such as quartz, diabase and granite preferred to stronger materials like materials of/or rich in alumina,

silicon carbide and silicon nitride and/or particles of strong metals like steel or alloys of steel in concentration by volume of at least 30%, preferably at least 40%, more preferably at least 50%, yet more preferred of at least 60%, most preferred of at least 65% by volume based on the total composite material.

Finally, there are interesting particle-based composite materials for articles according to the invention, which has both fine and large particles, having

a) a high concentration of "fine" particles and a moderate to high concentration of "larger" particles, or

b) a moderate concentration of "fine particles" and a high concentration of larger particles, or

c) a relative high concentration of both "fine" and larger particles.

Such composite materials are generally characterised by having a very high concentration by volume of strong, rigid particles referring to the sum of "fine" and larger particles.

2. Beyond containing strong, rigid particles the composite materials also contain elongated fine, strong, rigid components, typically in the form of discrete fibres, threads, fabric or web, and suitable but not always in high concentrations by volume, characterised in that the particle-based composite materials contain elongated particles as discrete fibres in a concentration by volume of 0.1 - 1% and/or 1 - 2% and/or 2 - 5% and/or 5 - 10% and/or 10 - 20% and/or 20-60%.

In many of the composite materials for articles according to the invention the fibres only serve the main object of imparting toughness. The proportion by volume of fibres is often so low (e.g. 2% or less) that it has only a marginal effect on the rigidity of the beforehand particle strengthened materials and also has only marginal effect on the amount and the size of the particles which practically can be incorporated into the composite material.

At high fibre content, e.g. 10 - 20% by volume, in particular 20 - 60% by volume and quite particular about 60% by volume of fibres, the fibres have a marked effect both with regard to the contribution to rigidity and with regard to the interaction with particles. For example there are very interesting composite materials for articles according to the invention having high rigidity and rupture-toughness, characterised by a) very high content of fibres and b) correspondingly low content of "particles", optionally entirely without "particles".

3. For hybrid articles according to the invention the said composite materials are combined with strong, rigid components, e.g. of steel, in the form of slabs imparted profile form.

For hybrid articles according to the invention based on plastic or corresponding less rigid binding agents in the composite materials the route described from 1- 3 can be characterised by:

1. With particles in very high concentrations the plastic materials (considered in relation to the pure plastic material concerned) is imparted very high rigidity and very high compression strength and substantially "unchanged" tensile strength and very small yielding with regard to deformation up to maximum of stress.

2. With fibres the above hard but fragile plastic composites are imparted very high rupture - rigidity, i.e. high deformation performance and energy capacity in connection with crack zone deformation and crack opening as related to the behaviour after maximum of stress.

3. With the - as regards rigidity, compressive strength and rupture-toughness - completely changed material behaviour we have naturally to renounce from conventional plastic-metal hybrid construction (cf. gluing etc.). Plane-sheet-plastic composites changed as stated under 1 and 2 will suffer of the same weaknesses as mentioned generally for hybrid structures (careening-rupture etc.). The unique hybrid behaviour of

plastic-based articles according to the invention is secured by forming hybrid constructions with use of profiled strong rigid sheets.

The invention is defined by requirements to the properties/combination of properties for composite materials supplemented with requirements as to how such properties are obtained.

A different way of expressing the invention is by primarily focusing on the approaches made for obtaining the properties and combinations of properties for the composite materials of the hybrid articles which by incorporation into the intimate contact with the profiled sheets forms the articles/constructions of the invention or parts thereof.

Objects composed of or with particle based composite materials in intimate contact with profiled sheets preferably placed entirely or at least essentially external to the bodies composed of the composite materials, forming the hybrid articles are characterised by that:

a) binding agents of the composite materials are based on strong/dense cement paste - and/or other binding agents like plastic based binding agents containing fine particles of sizes as cement and optionally also finer particles characterised in that the proportion by volume of cement, including fine particles of cement fineness or finer such as micro silica, prior to the solidification is at least 50%, preferably at least 55%, more preferably at least 60%, yet more preferably at least 65%, most preferably at least 70%, and

b) the composite materials contain elongated particles such as discrete fibres in concentration by volume of 0.1 - 1%, and/or 1 - 2%, and/or 2 - 5%, and/or 10 - 20%, and/or 20 - 60% or higher than 60%, and preferred

c) the composite materials contain larger, rigid, strong particles like particles of natural strong rocks such as quartz, diabase and granite, preferred of stronger materials like materials of/or rich in alumina, silicon carbide and silicon nitride and/or particles of strong metals like steel or alloys of steel in concentration by volume of at least 30%, preferably at least 40%, more preferably at least 40%, yet more preferably at least

50%, still yet more preferably at least 60%, most preferably at least 65% by volume based on the total composite material, and

c) the plate elements are strong characterised by a tensile strength of at least 100 MPa, preferably at least 200 MPa, more preferably at least 350 MPa, yet more preferably at least 500 MPa, still yet more preferably at least 700 MPa, most preferably at least 1000 Mpa.

In a particular aspect the invention concerns articles wherein composite materials without or with only low content of larger particles are incorporated.

As to the mere particles such composite materials can be composed of a) exclusively cement particles and particles of cement fineness or finer and/or b) also containing slightly larger particles, e.g. particles having sizes from 100 μm, 250 μm or up to 1 mm.

Composite materials of this category is particularly of interest for a) articles/parts which are very thin having e.g. thicknesses of less than 10 mm or less than 5 mm or less than 2 mm, and/or b) articles having a very confined internal structure, e.g. in articles having a very high fibre content such as 2 - 5%, and/or 5 - 10%, and/or between 10% and 20%, and/or between 20% and 60%, and/or higher than 60%.

Manufacture.

Production of components composed of 1) strong cement-based materials, more generally of strong particle-based composite materials in intimate contact with 2) profiled sheets includes:

1. Production of composite materials, e.g. strong cement-based materials of the Densite-type.
2. Production of profiled sheets, e.g. profiled steel sheets.
3. Securing intimate contact between the components described under point 1 and 2.

Production of composite materials, e.g. cement bounded materials, can be effected in accordance with known technology for producing the respective composite materials.

Similarly the production of profiled sheets can be effected according to known technology for the production of such sheets.

The instant invention concerns processes and methods of joining together components for obtaining intimate contact - and for integral production where e.g. profiled sheets function as form or tool in connection with the production of the composite materials - or where the composite materials conversely function as form or tool in the production of the profiled sheets.

In one aspect the invention concerns processes wherein the profiled sheets function as mould sides in processes wherein the composite components are imparted their final shape and final position in intimate contact with the profiled sheets.

The shaping can be effected with pouring masses which are poured or pressed against the profiled sheets, preferably assisted by mechanical vibration.

These methods include pouring masses which in fresh condition before solidification are easy flowing to plastic and rigid plastic. The methods include compacting pressure of from 10 or 100 Pa which corresponds to the own weight of thin layers of up to 10 or 100 MPa or more as with high pressure compression.

A particular aspect of the shaping can be effected by smearing or spraying the pouring masses on to the sheets.

A particular aspect of the invention concerns processes which combine the above methods, e.g. by succeeding a smearing or spraying with pressure compression frequently preferred with oscillating pressure (vibro compression).

In an other aspect of the invention a part of or all the components of the composite material - larger particles, fibres etc. - are preplaced in contact with the profiled sheets whereupon the cavities between these components are filled out by infiltration with liquid binding agent, e.g. assisted by vacuum and/or external pressure.

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In another aspect of the invention intimate contact between the sheet and the fine particles + liquid of the composite pouring mass is first provided and then the coarser parts are applied in contact with the fine particles + liquid. In one aspect of the invention this is effected in fresh condition under simultaneous displacement of the said finer particles + liquid up between the coarser particles and components. The process can be effected by centrifugation or by external pressure possibly assisted by internal vacuum to secure against inner air accumulations.

In another aspect of the invention substance composed of finer particles and liquid which penetrate into the confined cavities, e.g. between closely spaced reinforcement or into the roughness in the sheets, is as above first applied followed by a pouring mass containing both fine and coarse particles + liquid which displace the finer particles - liquid system from the areas wherein the coarse particle system can penetrate into and which simultaneously leaves the confined interstices, wherein the coarse particles cannot penetrate, filled with the fine particles - liquid material.

After having shaped the pouring masses in intimate contact with the sheets the pouring masses solidify, e.g. by hydration in case of cement bound materials, solidification in case of thermoplastic materials, and polymerisation in case of thermosetting plastic materials.

For a large number of processes according to the invention final contact between the sheet element and the sheets has thus also been obtained.

Interesting aspects of the invention concern specific measures at the interface between the composite materials, such as gluing. In one aspect of the invention the solidified materials are separated from the sheet after which adhesive is applied on one or both surfaces whereupon they again are brought in intimate contact and the adhesive solidifies then.

In another aspect of the invention the adhesive is applied on the surface of the sheets before pouring and hardening, e.g. in the form of a solid film. After the composite

materials are placed in contact with the sheet and also in direct contact with the applied solid film the latter is melted by heating and then allowed to solidify and to form the desired adhesive joint.

In another aspect of the invention the composites and the sheet are prepared separately and are then assembled in intimate contact, e.g. maintained by gluing.

In a particular aspect of the invention the composite material article is first produced and then the sheet part is prepared by processes in which the sheet element is brought in intimate contact with the surface of the composite material article. Processes of this category can be based on plane sheets which assisted by pressure, optionally vacuum and heating are shaped so as to follow the outer contour of the composite article. By way of example it may be vacuum shaping of plastic sheets or pressure shaping of sheets of superplastic metal, both processes typically at increased temperature.

Another often preferred technique is galvanotechnique wherein a metal shell is deposited on the surface of the composite articles in galvanic bathes. Other techniques within the scope of the invention are based on other well known coating techniques such as plasma spraying technique and chemical vapour deposition. Just as in the processes wherein the sheets are first produced it is also possible in the shaping of sheet or shell on the finished composite articles simultaneously to establish the final contact, or the processes are first based on separation of the shaped sheets or shell from the composite articles and then joining them together again in succeeding processes, e.g. by gluing.

Hybrid construction according to the prior art. - Example.
We will now consider a typical composite construction of concrete and profiled steel sheet according to prior art.

The example is taken from "Steel Designers Manual" where it is used as text book syllabus for illustration of how such composite slabs are designed in accordance with the British Standard.

The item is a cover construction in form of a plate having a span of 3 m, simple supported along two edges, designed to absorb even distributed loading. The cover plate is composed of (at the bottom) a profiled steel sheet and (at the top) concrete.

Profile: Z-shaped height	50 mm
Top and bottom flange	125 mm
Body inclination (horizontal/vertical)	25/50
(deviation from vertical)	
Sheet thickness	1,2 mm
Steel quality, yield point	280 N/mm
Cover thickness (concrete + steel sheet)	75/125 mm
Mean	100 mm
Compressive strength of concrete	30 N/mm^2 (cube).

In "Steel Designers Manual" calculation is made of the maximum moment which can be absorbed by the plate if it functioned effectively as composite article, i.e. without shear failure between concrete and profile sheet (e.g. secured by particular mechanical measures).

Plastic moment of resistance M1:31,800 N. (Moment per meter).
Based on experiments with such plates the real condition at rupture is then shown in "Steel Designers Manual". Rupture occurs at a substantially lower loading, not in bending but due to shear failure: maximum shear force. Vu = 21,800 N/mm.

Based on the above start data the result of calculations of corresponding maximum stresses in an analogue homogenous elastic plate, i.e. a plate having the same outer measures as the composite plate but composed of homogenous, isotropic material having a linear elastic behaviour, is shown below. The calculations are based on theory for a simple beam.

The results are shown below in the scheme:

	Shear failure in real state of rupture.	Theoretical calculated presuming effective composite action with bending failure.
Maximum tensile stress	12.5 N/mm^2	24.3 N/mm^2
Maximum shear stress	0.42 N/mm^2	0.82 N/mm^2
Even distributed loading	14.5 kN/m^2	28.3 kN/m^2

Scheme: Maximum stresses in analogue elastic plates corresponding to 1) real behaviour, and 2) behaviour on condition that effective composite action was established, and the evenly dispersed loadings corresponding to the two rupture conditions.

The results emphasise the insufficient co-operation between the profiled sheets and the concrete in conventional constructions/articles.

Thus, the real loading at rupture is only about 50% of the loading which the plate would be able to carry if shear failure was avoided. Thus, the carrying capacity corresponding to composite behaviour cannot at all be utilized.

The results are also applied in estimation of what is obtained by the measures taken by the present invention, comparisons being drawn as to what was obtained purely physically with the plates of the invention shown in example 1.

Thus, in the articles according to the invention in example 1 shear stresses of 19 N/mm^2 occurred which is 19/0.42 = 45 times more than in the above conventional composite plate at its failure.

As no shear failure occurred in the article according to the invention the shear capacity is in reality still higher. Thus, the shear capacity is at least 45 times higher than that of the composite article according to the prior art.

This is very surprising as seen in the light of 1) the strength of the concrete is only increased corresponding to about a factor 10 and furthermore, of 2) the shear resistance at failure between concrete and steel sheet is conventionally not at all increased by increasing the strength of the concrete (vide the calculation example).

CALCULATION EXAMPLES

In the following some calculation examples will be demonstrated to illustrate the interaction of the plate composite material in a) articles according to the prior art and b) articles according to the invention with particular reference to shear failure. We consider a simplified system wherein a thin metal sheet is pulled relative to a concrete body as shown in fig. 9. The figure shows in cross-section a thin metal sheet 1, of thickness t and modulus of elasticity Ea, fixed on the outer side of a body formed of composite material affected by a force 3 (F) acting in the direction of the sheet.

In connection with illustration of pure shear it is immaterial whether the sheet is plane or profiled. Therefore, it is chosen to discuss (illustrate the physic in the light of the shown simple plane - sheet hybrid construction).

With increased displacement the zone propagates within which the forces are transmitted, in the following designated the displacement zone. When the displacement at the point of force attack has reached the maximum value for acting force transmitting the displacement zone has reached its maximum extension (Lc) and the force, which is transmitted, has reached its maximum size (F=Fc).

Further stressing (removal of the point of force attack) results in removal of the displacement zone away from the edge but with maintainance of the force F=Fc. What is gained by utilizing material farther in is lost due to failure of force transmittance

above the active zone. The figure illustrates this situation with the force transmittance zone 5 a distance within the article and a front crack 5.

The behaviour can be described as shown below where an idealized case is considered, i.a. having a linear elastic behaviour and a constant shear stress (To) throughout the zone of action (Lc).

<u>Model complex 1</u>

Tensile force in sheet	Fc = $\sqrt{2EaGt}$ (N/mm)
Maximum tensile strength in sheet	σ = $\sqrt{2EaG/t}$ (N/mm^2)
Zone of action	Lc = $\sqrt{2EaGt/}$ (mm)

Ea: Modulus of elasticity of the sheet element, G: energy of rupture at shear failure, τo: Shear strength, t: Sheet thickness.

As it is seen from the model that the modulus of elasticity of the sheet element forms part of the expression for the carrying capacity. In the illustrating example chosen to give maximum of clarity/survey, only the rigidity of the sheet took part. In the real systems the rigidity of the concrete is also of importance. The effect goes in the same direction, viz. a higher E-modulus for the concrete results in a larger zone of action and a higher carrying capacity.

The energy of rupture related to displacement forms part of this simplified model even though such quantity is not unequivocally defined according to the literature of the art and even though it is chosen in this patent description to relate requirement with regard to rupture-toughness to the energy of rupture at tension. The reasons for using energy of rupture related to tension is found in this specification, i.a. in the paragraph concerning "definitions and explanations".

1. Behaviour illustrating existing composite slab according to prior art

Composite slab having high similarity with an actual plate used as example in design of "composite slab" in "Steel Designers' Manual" (composed of concrete and profiled

steel sheet, 1.2 mm thick sheet with trapezoidal profile) with respect to concrete, sheet element and sheet thickness.

Starting data:	Max. local shear stress	$\tau o = 5\ N/mm^2$
	Sheet thickness	$t = 1\ mm$
	Energy of rupture	$G = 0.1\ N/mm$
	Modulus of elasticity of the steel sheet	$Ea = 2 \times 10^5\ N/mm^2$

The state of rupture at shear failure is found from the model.

Max. tensile force in the sheet	$Fc = 200\ N/mm$
Max. tensile stress in the sheet	$\sigma = 200\ N/mm^2$
Extension of the zone of action	$Lc = 40\ mm$

This illustrates a (frequently undesired) fragile behaviour of force transmittance concentrated across a very small part of the contact area.

Viewed in the light of the example from "Steel Designers' Manual" concerning a simple supported slab having a span of L = 3.0 m this means e.g. that the shear forces are to be transmitted across a distance of about Lc = 750 mm. As it is seen from the value for the extension of the zone of action Lc, the transmission of the forces takes place on a distance of only Lc = 40 mm, thus, on only about 5% of the shear area. This means in turn that the shear stress in average is only about 5% of the maximum:

$$\tau = 5 \cdot \frac{40}{750} = 0.27\ N/mm^2$$

Viewed in this light it is not surprising that through numerous experiments and experiences in practise within the prior art, recognition has been reached about the weaknesses with conventional composite slabs as regards shear failure as i.a. it appears from "British Standard", cf. the above quotation concerning order of utilizing such hybrid constructions where utilization requires "composite action" (vide page).

2. Evaluation of the effect of improved concrete quality/steel quality for existing composite slabs according to prior art .

With starting point in the numeral values in calculation example 1, we will now show why even modest benefit is not obtained with thin slab concrete hybrid constructions according to the prior art by using stronger materials (concrete/steel), but instead often definitely inferior behaviour with stronger materials contrary to what would be expected from general teaching of constructions.

Concrete quality - strength

With increasing strength of concrete obtained e.g. by reducing the proportion between water and cement, the shear strength will also be increased. Thus, from the design principles according to the prior art a doubling of the shear strength would be expected to result in the double shear carrying capacity of the composite slabs. This is, however, not the case. An increase of the strength of the concrete by reducing the water/cement ratio result in a more fragile concrete. Thus, a doubling of the strength will usually only have marginal effect on the E-modulus and the energy of rupture. In many cases, the energy of rupture will even be reduced due to the fact that rupture etc. will rather pass through aggregate than round it as it happens in weak concretes.

If, in addition to the above rough estimates, we presume that the energy of rupture remains unchanged ($G = 0.1$ N/mm) when the strength of the concrete is changed and hence alto τo, a twofold and fivefold increase, respectively, of τo is achieved as shown in scheme 1 below.

τo N/mm²	Fc N/mm	σ N/mm²	Lc mm	Lc/0.25L %	τav N/mm²	
5	200	200	40	5	0.27	calculation values from example 1.
10	200	200	20	2.5	0.27	actual values with stronger
25	200	200	8	1	0.27	concrete

By way of example, the size of the area wherein the forces are transmitted is shown in the penultimate made column, indicated in % of the total contact area of the above slabs having a length L = 3 meter. In the ultimate column the average shear stress is stated.

As it is seen, no improvement regarding shear capacity (Fc) and utilization of the steel (σ) is obtained. What only occurred is that the small force transmission zones have been further concentrated (from an extent of 40 mm down to only 20 and 8 mm, respectively, corresponding to only 2.5 and 1%, respectively, of the area which is available for the absorption of the shear forces).

Viewed in the light of this numerical example the conclusion must be: No improvement, the same shear capacity. In reality, the conditions have become worse than it is expressed in the scheme. The articles are far more fragile and sensitive to local stresses and fissures.

Steel quality - strength

As it is seen from model complex 1, nothing is obtained with maintained sheet thickness by using much stronger steel, e.g. with a twofold or fivefold strength. With maintained sheet thickness (in the example t = 1 mm) the data shown in scheme 1 are obtained in all cases, as the behaviour depends exclusively of the rigidity of the steel (modulus of elasticity), which is unchanged by using stronger steel, and not on the

yield stress and strength (as far as these - with reference to the example - are above 200 N/mm^2).

Thus, this means that according to conventional technical know-how the carrying capacity of composite slabs cannot be doubled/quintupled by doubling/quintupling the strength of the main components (concrete and steel sheets). If attempted, the effect becomes at best an unchanged behaviour.

Effective utilization of the sheets elements

If it is contemplated to utilize much stronger steel having e.g. a yield stress of 800 - 1000 N/mm^2 in order to save materials the situation becomes far worse.

Let us consider what happens if the sheet thickness is halved, i.e. reduced from t = 1 mm to t = 0.5 mm. (In this hypothetical example illustrating the principles it is ignored that sheet thicknesses of 0.5 mm for other reasons may have weaknesses. By way of example the same result shown below could have been obtained if in similar systems 10 mm sheets were reduced to 5 mm sheets). From model complex 1 the values shown in scheme 2 are obtained.

SCHEME 2

τo N/mm^2	Fc N/mm	σ N/mm^2	Lc mm
5	141	282	28
10	141	282	14
25	141	282	6

As it is seen by comparing the values in schemes 1 and 2 the thinner, stronger sheets of scheme 2 result in inferior carrying capacity, viz. a reduction of 30% of the beforehand very small shear carrying capacity. The zones of action have also become re-

duced by 30%. The steel quality is not utilized so effectively as desired - only corresponding to an increase of 40% where conventionally a halving of the sheet thickness would be expected to result in a doubling of the stresses.

If it was desired to utilize e.g. steel of double strength (e.g. having yield stress of 600 in stead of 300 N/mm^2) the sheet thicknesses should be reduced to 1/4. This would lead to a halving of the shear capacity and a halving of the beforehand extremely small displacement zone. All in all, the use of high steel quality in order to reduce sheet thicknesses will according to conventional technical know-how result in inferior carrying capacity at shear and higher fragility.

3. Behaviour illustrating composite slab according to the invention having similarity with the composite slab described in example 1 (having regard to sheet thickness and properties of composite materials)

Starting data

Max. local shear stress	$\tau o = 25$ N/mm^2
Sheet thickness	$t = 1$ mm
Energy of rupture	$G = 3.6$ N/mm (3600 N/m)
modulus of elasticity (steel sheet)	$Ea = 2 \times 10^5$ N/mm^2

In the state of rupture at shear failure, it is found from the model:

Max. tensile force	$Fc = 1200$ N/mm
Max. tensile stress in the sheet	$\sigma = 1200$ N/mm^2
Extent of the zone of action	$Lc = 48$ mm

In the composite slab of the invention shown in example 1 (free span 287 mm loaded with a central line loading) the shear forces are to be transmitted between loading and support which is an area having an extent of only 144 mm (compared to 750 mm in the described known slab construction, cf. calculation example 1). This means that the

actual transmission occurs on 48/144 = 33% of the total displacement area (and not as in calculation example 1 on only 5%). This means correspondingly that the shear stress in average becomes $\tau av = 25 \times 0.33 = 8$ N/mm^2.

Thus, compared with the figures of example 1 (F = 0.27 N/mm^2) the shear resistance has been increased with about 30 fold.

This must be very surprising to the man skilled in the art - not only the great number, but also the fact that the shear resistance was increased as much as six times more than the shear strength which was only increased by a factor 5 (from 5 to 25 N/mm^2).

Thus, "very surprisingly" as much as six times more benefit is obtained with the increased shear strength compared to what could be expected according to the technological know-how of the prior art.

Compared to the results from the experiences of the prior art as regards negative effect of stronger concrete (and steel) as demonstrated in calculation example 2 the results are yet more surprising to the man skilled in the art within the known technology.

From scheme 1 it appears e.g. that with very high shear strength ($\tau o = 25$ N/mm^2) obtained only by improving the strength of the concrete without - as in accordance with the invention - also simultaneously increasing the energy of rupture pronounced, the mean value of the shear stress is not increased.

This means, very surprisingly, that - based on the figures of the present example - with materials having the same shear strength, $\tau o = 25$ N/mm^2:
a 30 fold improvement of the shear capacity is obtained by the invention

compared to analogue systems with quite as strong concrete but without incorporation of the quite essential rupture-toughness which is characteristic for the composite ma-

terials of the present invention. The mean shear stress was increased from 0.27 N/mm^2 to 8 N/mm^2.

4. Estimate of composite slabs according to the invention - broader perspective

As viewed from calculation example 3 as starting point we will discuss/evaluate the different aspects of the present invention, still with model complex 1 as tool.

Large articles

An essential feature of the design strategy, which is the basis for design of many articles within the present invention, is regard to the fact that the degree of fragility/toughness does not only depend on the materials, but also on the size of the articles. As illustration we will now consider articles like those described in calculation example 3 and shown in example 1 but ten times larger. With reference to example 1, this means e.g. slab constructions having a span of about 3 m, height 80/300 mm, and a profiled steel sheet having a thickness of 10 mm.

We will consider articles:

a) prepared of exactly the same composite material as in calculation example 3,
b) of materials adapted so that the behaviour of the large articles becomes similar with the behaviour of the slab shown in calculation example 3.

a) Of the same materials

Max. local shear stress	τo = 25 N/mm^2
Sheet thickness	t = 10 mm
Energy of rupture	G = 3,6 N/mm (3600 N/m)

The state of rupture at shear failure is found from model complex 1:

Max. tensile force in sheet	Fc = 3800 N/mm
Max. tensile stress in sheet	σ = 380 N/mm^2
Extent of zone of action	Lc = 152 mm

Decisive, it is an interesting composite slab according to the invention, but compared to the system in calculation example 3 a tenfold increase of the tensile force of rupture in the steel sheet has not been obtained with the ten times thicker sheet, and the steel is neither utilized so effectively.

It is also seen that the transmission zone has become relatively smaller than in the small sheet, viz. 152/1440 = 10.7% compared to 33% and that the average value of the shear stress has become correspondingly smaller, viz. 2.5 N/mm^2 compared to 8 N/mm^2 in the small sheet.

The value is yet still very high compared to that of the prior art, cf. calculation example 2 (τav = 0.27 N/mm^2). With τav = 2.5 N/mm^2 the shear force per area is about 10 times larger.

b) Of materials improved/adjusted with regard to degree and toughness

According to the design principles used in designing articles according to the present invention, similar behaviour will be obtained for geometric similar articles, e.g. 10 times larger articles, of materials having the same strength and rigidity by simultaneously increasing the energy of rupture by a factor 10. This means that in the actual case, we will have to increase the energy of rupture from 3.6 N/mm to 36 N/mm (36000 N/m). This is technical feasible.

Typically it is effected by increasing the fibre content (e.g. from the actual one of 1.1% used in the articles shown in examples 1-6 or 9%) and modifying the fibre geometry and the particle geometry adapted to the larger articles.

Starting data

Max. local shear strength	$\tau o = 25$ N/mm^2
Sheet thickness	t= 10 mm
Energy of rupture	G = 36 N/mm (36000 N/m)
Modulus of elasticity (steel sheet)	$E = 2 \times 10^5$ N/mm^2

From model complex 1 it is found:

Max. tensile force in sheet	Fc = 12000 N/mm
Max. tensile strength in sheet	$\sigma = 1200$ N/mm^2
Extent of zone of action	Lc = 480 mm

Again we have obtained the same/similar behaviour with large articles as previous with the small, tough slabs.

That is:

Transmission unto 33% of the displacement area; mean stress $\tau av = 8$ N/mm^2 (30 fold increase of the shear resistance as compared to conventional technique, cf. examples 1 and 2.

5. Carrying capacity of 3 m composite slab according to the prior art and according to the invention

Based on a) a composite slab according to the prior art, described in "Steel Designers' Manual", see "Hybrid Constructions according to prior art", and b) the tested composite slab according to the present invention, cf. example 1, comparisons of the carrying capacities have been performed.

We consider simple slabs having a span of 3 m, supported along opposite edges and loaded with an evenly distributed loading. The slab of the prior art (according to Steel Designers' Manual) is exact as described.

The slab constructions according to the invention are geometric similar with the tested one (cf. example 1) as regards cross section. Simultaneously, the rupture-toughness is adjusted (as in 4) so that the behaviours become similar. Based on the moment capacity (moment of rupture) experimentally found in example 1 the moments of rupture have been calculated from classical beam theory for the larger similar slab constructions and from that in turn calculated the corresponding loadings of rupture.

Slab construction	height	mean slab thickness			loading at rupture
		thickness		pressure	meter water
	mm	mm	mm	kN/m^2	m
according to prior art	125	100	1.2	14,5	1.45
according to the invention	125	53	4.2	204	20.0
	236	100	7.9	728	73.0
	316	135	10.5	1,306	131.0

The carrying capacity of composite articles with profiled steel sheets in contact with "concrete".

Loading at rupture is expressed in terms of pressure of an evenly distributed loading, partly in kN/m^2, partly as meter of water column. The carrying capacity of the slabs according to prior art is stated in "Steel Designers' Manual" from which they are quoted.

The slabs of the prior art are designed so as to resist evenly distributed loading of 5/KN m^2. The loading of rupture is 10 KN/m^2. The own weight of 2 KN/m^2 is included therein. Failure occurs by shear rupture along the steel sheet and the concrete.

(If shear failure was prevented and slab failure in stead occurred due to plastic yielding at bending, the carrying capacity would have been nearly the double - 28.3 kN/m^2.

As it appears, the invention provides for:

a) for slabps of the same height (125 mm) and only 53% by volume of material: 14 fold higher carrying capacity corresponding to a loading with a 20 m column of water compared to 1.45 m for the reference of the prior art,
b) for slabps of the same volume of material and scantily the double height, the carrying capacity is above 50 times higher corresponding to a loading with a 73 m high column of water,
c) for the somewhat stronger slab which is exactly geometrically similar with the small slab dealt with in example 1 of the patent specification, the carrying capacity is 90 times higher and the loading of rupture corresponds to a 130 m column of water compared with 1.45 m for the reference of the prior art.

The material volume of the slab is, as it appears, only 35% greater than that for the reference slab.

With reference to a) and b) it is seen - utmost surprising to the man skilled in the art - that by increasing the strength of the concrete with a factor of about 8 (from 30 to 250 N/mm^2) and simultaneously increasing the sheet thickness with about 3.5 to 7 times (from 1.5 mm to 4.2 and 7.9 mm, respectively) of steel of not essentially different quality, a 14 and 50, respectively, times higher carrying capacity is obtained.

Thus, the carrying capacity is about 2 to 6 times higher than one would expect according to conventional technology with the stated increases in material strength and steel sheet thickness, if the well-known fact erroneously was ignored that (due to composite action) the estimated positive effect of stronger concrete for profile sheet/concrete composites will nothing like approximately be obtained. If consideration is paid thereto the figures are yet more surprising to the man skilled in the art concerning the known technology.

It should further be stressed that the values related to the slab constructions according to the invention, cf. example 1, was based on experiments with slab constructions which failed by rupture in bending, due to yielding in the steel sheets and not due to shear failure, as was the case for constructions according to the prior art.

This indicates that e.g. with steel sheets of higher quality a still higher carrying capacity can be obtained before the limit is reached where failure happens due to shear.

ARTICLES - EMBODIMENTS OF CONSTRUCTION

The desired behaviour is secured with the strong, rigid and simultaneously very tough composite materials combined with sheets having profile shape.

The invention comprises a wide scope of profile embodiments and slab elements and slab thicknesses.

A group of particularly interesting constructions according to the invention are constructions wherein the profiles are trapeziform - thus not rounded - and here again such wherein the side walls are steep (i.e. the angle between the web and the flange is large, e.g. 44°, optional 60°, optional 70° or optional 80° or 90°). Such embodiments increase intimate mechanical co-operation between the sheet profile and the composite material, e.g. so as to counter longitudinal displacement.

A particular aspect of the invention concerns constructions composed of profiled sheets and said composite materials further reinforced with reinforcement imbedded in the composite materials, typically in the form of bars, threads and wires.

Principally, the reinforcement can be of any material and having arbitrary strength and rigidity.

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In preferred constructions according to the invention the reinforcement is strong having tensile strength of at least 500 MPa, preferably at least 700 MPa, more preferably at least 1000 Mpa, yet more preferably at least 2000 Mpa.

An example of preferred reinforcement is cold drawn thread of steal having a tensile strength of 1800 MPa, 2000 Mpa, or 2000 - 2500 Mpa. The reinforcement can be in the form of separate threads or combined threads forming e.g. cables.

Particular aspects of the invention concern profiled sheets and composite materials according to the invention reinforced locally or globally. A particular aspect of the invention concerns articles profiled in more than one direction.

A particular aspect of the invention concerns constructions according to the invention provided with extra sheets.

The extra sheets can serve particular purposes. The sheets can e.g. be the inside of rooms (containers, silos etc.) containing materials, substances which are chemical agressive to the other sheet element. The extra sheets can i.e. also serve purposes which are related to their form, e.g. smooth surfaces facilitate cleaning and reduce fractional resistance at internal of material movement (liquid movement in pipes, powder movement in pipes and silos etc.).

The extra sheets can also be part of the bearing construction for strengthening both in longitudinal and cross directions against bending stresses and for increasing the rigidity.

The joining of the profile sheets and the extra sheets can be effected by reveting, bolting, welding such as e.g. spot welding, glueing and soldering etc..

The sheets can also be placed in contact with the composite materials.

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Extra sheets placed in contact with the composite materials can serve the same purposes as mentioned previously, and as permanent shuttering/mould side during moulding of the composite materials.

Extra sheets can have a form deviating from plane or even curved shape. A particular aspect of the invention is constructions wherein extra sheets are profiled. The invention.

As mentioned, the invention concerns sheet formed components. It may be sheet formed components which are plane as will be the case e.g. when the components form plane limitations such as e.g. floors, ceilings or walls in box-shaped constructions as e.g. containers etc.

The components can also be curved, typically slightly curved as will be the case when the components form limitations which are curved as in tanks, pipes having curved surfaces and shutter constructions.

Articles according to the invention will typically contain components in the form of sheets. Components according to the invention can also be construction elements such as beams or columns.

Articles according to the invention can also be objects composed of components previously mentioned and/or construction elements such as pipes, containers, doors, gates, walls, cabins, ceiling constructions, thermo-boxes, refrigerating rooms, heating rooms, security rooms, boilers, cooling towers, chimneys, bridges, top layers for roads etc.

A particular aspect of the invention concerns articles repaired with articles reinforced with the profile sheet composite materials composed according to the invention. It may be e.g. articles as those mentioned in the preceeding paragraph. The articles, which are reinforced with the components according to the invention, can be of arbi-

trary solid material as e.g. metal, wood, plast, tile, concrete, gypsum, natural stones, glass and ceramic.

Special articles according to the invention are articles usable within the machine area such as e.g. motors, pump housings, pumps, moulding tools, moulding machines and especially for use within areas where a low weight/strength ratio is of great importance such as in connection with fast moving/rotating components and within the transport area (aeroplanes, ships, automobiles etc.).

Special articles according to the invention are wear resisting and/or smooth objects in which the especial friction and wear properties of either the sheet elements or the composite materials, typically are utilized.

Example 1

Slab construction according to the invention - production and mechanical testing.

Construction: The slab construction is composed of profiled steel sheets in intimate contact with strong, tough, fibre reinforced cement-based composite material. A fragment of the slab cross section is shown in Fig. 10. Steel sheets 1 (1 mm thick) constitute about 13% of the total volume of the slab construction.

In addition to the profiled sheets the construction is reinforced with longitudinal and transverse reinforcements placed at the top side 2, 3. The transverse reinforcement rods (diameter 3 mm) are placed with a center distance of 150 mm.

The reinforcement contributes only to stiffen the construction - not to absorb the high tensile stresses at the bottom during bending loading. (There are other preferred articles having also longitudinal reinforcement placed at the bottom, which are still stronger. The purpose was, however, here to test/demonstrate the mode of action of the purely profile reinforced hybrid construction).

The composite materials 4 was placed dense and homogenous - (with "incorporation" of less than 1% air). As from the recipe and an approximate knowledge of the densities of the components included, the volume proportions of "particles" was calculated (referring to the state prior to the chemical structure formation by the reaction of the cement with the water).

Cement + micro silica + dispersant	35.7%
Sand (calcined bauxite)	46.1%
Steel fibres	1.1%
Water	17.1%

Scheme.

Components included in the composite material indicated in % by volume.

If we disregard the insignificant contribution to the total volume from the admixed air and dispersant (in total below 2%) this implies the following proportions by volume:

Binder alone.

Particles (cement + micro silica)	68.0%
Liquid	32.0%

Composite material.

Larger particles (sand - bauxite)	46.0%
Steel fibres	1.1%
Binder (particles + liquid)	53.0%

Scheme.

Proportion by volume in binder (uppermost) and in the total composite material (lowest).

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Compressive strength.

250 N/mm^2.

Energy of rupture.

The energy of rupture of the composite material is estimated from experiences with very closely related materials to be about 3000-4000 N/m (3.0 - 4.0 N/mm).

Materials:

Steel sheet: 1 mm cold reduced fine sheet ST 12.

Mechanical properties:	yield point (ultimate stress) = 270 (410) N/mm^2.
	yield limit max. = 280 N/mm^2.
	elongation at rupture min. (L = 80 mm) = 28%
	hardness HRB max. 5 = 65.

Profiling effected by bending. (Information from the supplier).

Reinforcement:

4 pieces ø 6 mm cam steel. Tensile strength = 4200 kg/cm^2 (longitudinal)

3 pieces ø 6 mm cam steel. Tensile strength = 4200 kg/cm^2 (transversal)

Cement based composite materials:

Densit-binder supplied from Densit A/S. Densit binder contains about 80% Portland cement (white cement) and about 20% micro silica (50-100 times finer than Portland cement) and a minor amount of dispersive agent in powder form.

Strong sand:	0-1 mm and 1-2 mm of baked bauxite (Al_2O_3 rich material).
Steel fibres:	ø 0.4 x 12 mm, strength 4200 kg/cm^2. Supplier: Densit A/S
Water:	Tap water.

Recipe:

Densit binder:	8000 g
Bauxite 0-1 mm:	8000 g
Bauxite 1-2 mm:	3400 g
Steel fibres 0.4 x 12:	600 g
Water.	1280 g

Preparation:

Mixing equipment:	Forced mixing machine.
Mixing time:	Dry mixing 5 min. Wet mixing 8 min.
	Wet mixing with fibres 5 min.
Moulding:	Soft moulding with vibration.
Hardening:	1 day and night at 15° - 20°C. 4 Days and nights at 50°C.

Quality: reference specimen hardened in the same manner (90 x 45 mm cylinders) showed a compressive strength of about 250 MPa. Energy of rupture, estimated: about 3000 - 4000 N/m.

Mechanical testing.

The disposition is shown in Fig. 11. The set up is a simple supported slab 1 supported at the ends and at the middle, thus in total 3 supports designated (R1, R2 and R3) for absorbing a vertical line loading P. The slab construction was loaded with a line loading P placed centrally on the one section. The outer support in the other section was maintained down. Thus, the loaded half of the slab act as simple supported at the free end and fixed/partly fixed at the middle support. The degree of fixing can be determined as the relevant forces were measured (outer loading P and the forces of reaction at all three supports R1, R2 and R3).

The forces and displacements were recorded during the loading experiment.

1. **Elastic area.** Characterized by approximately proportionality between the applied force and the displacement as well as substantial reversible displacements. The elastic area extends from loading P = 0 to about 30 KN.

At the upper limit is:

Applied force	P = 30 KN
Forces of reaction	R1 - 13 KN
	R2 = 20 KN
	R3 = -3 KN

After a transitional area there was a larger area with decisive plastic yielding.

2. **Plastic area.** With substantial constant action of force and great displacements (substantially irreversible). By way of example the applied force varies here only between 50 and 64 KN for displacements of about 8 mm, from 4 to 12 mm, compared to force variations from 0 to 30 KN for displacement from 0 to slightly below 2 mm in the elastic area. The condition with maximum loading given by maximum applied force P = 64 KN and corresponding forces of reactions: R1 = 30 KN, R2 = 37KN, R3 = -7 KN.

EVALUATION OF RESULTS.

In order to be able to collate/compare the carrying capacity of articles according to the present invention with other sheet articles, often of another size, form and with a different loading, it was chosen to consider the behaviour of:

Analogue articles with the same outer geometry but composed of isotropic materials which shows linear elastic behaviour in all the loading area.

The first comparison made is a comparison between behaviour of the composite articles according to the present example 1 and corresponding sheet articles having the same geometry but made of a homogenous material (e.g. massive quality steel).

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We consider what stresses will be induced in the analogue, strong, elastic article by the actual loadings.

We consider the conditions in the cross section under the loading (P).

The stresses are calcuated according to the theory of beams (ignoring local forces from the loading). The corresponding maximum moments are calculated from the known edge reactions (R1). The corresponding maximum tensile stresses (in the bottom side of the slab) are obtained by division with the moment of resistance of the cross section - and by a little extra calculation - also the maximum compressive stresses (in the top-side of the slab) and the maximum shear stresses.

	Max.	Elast.
Applied force (P), kN	64	30
Reaction R1, kN	30	13
Max. bending-tensile stress (in the bottom side) (N/mm^2)	319	138
Max. compressive stress (in the topside) (N/mm^2)	147	64
Max. shear stress (N/mm^2)	19	8

Maximum stresses in analogue elastic slab construction calculated according to the theory of beams, thus without regard to local/higher stresses from outer force action and at supports. Forces and reactions refer to an actual slab width of 320 mm.

The maximum bending-tensile stress for slabs/beams - actually 319 N/mm^2 - calculated from the analogue elastic slabs are often designated the bending strength (in English terminology *Flexural strength*). The shear stresses refer to the shear stresses acting on the distance between the loading and the free support R1. (They are not the absolute maximae as the shear stresses acting between the loading and the middle

support is 10-20% higher - 22 and 10 N/mm^2, respectively. The picture of the stress forces is illustrated in Fig. 12.

A section of the slab is shown representing 1) a quarter of the width (80 mm) and 2) in the longitudinal direction the part of the slab which is between the loading (marked P) and the free support (marked R1). During loading with a line load across the cross section at P maximum tensile stresses arise at the bottom and maximum compressive stresses at the top together with maximum shear stresses in the web near the flange.

While the maximum tensile and compressive stresses decreases towards the support (R1) the maximum shear stresses are constant all over the section surface A-B-C-D. By way of example this means that under maximum loading a total shear force of 20 x 143.5 x 19 = 54,530 N = 5.5 tons is absorbed in the section surface (20 x 143.5 mm). Thus, with reference to the horizontal section shown there is not only a local stress peak but also shear stresses representing the mean value all over the section surface in its full width and full longitudinal extension from the loading zone to the free support.

DISCUSSION OF EXAMPLE 1.

The experiment shows for the article according to the present invention intimate co-operation between the profiled sheet and the strong, rigid, cement-based composite material imparted high rupture-toughness.

Yielding behaviour occured in the article with pronounced yielding in the steel sheet in the tensile side (during the central loading) without any form of sliding between the sheet element and the composite material despite the very high shear stresses. The calculated shear stresses (19 N/mm^2) was 45 times higher than the corresponding one according to the prior art with mean stresses = 0.42 N/mm^2 referring to rupture at shear failure (cf. the paragraph "Hybrid construction according to prior art"). This demonstrates a very effective co-operation between the profiled sheet and the composite material. It should be further stressed that the real shear capacity of the com-

posite slabs must be higher than what corresponds to the mean stress of 19 N/mm^2 as the failure occured by bending and not by shear.

The high compressive strength of the cement-composite (about 250 MPa) allowed use of a very thin layer of composite material (8 mm) and hence a corresponding modest material consumption and low weight.

This guiding experiment can furthermore be used as basis for the discussion of different other aspects of the invention:

1. **Combinations of slabs and very strong reinforcement rods.** Reinforcement threads/rods placed close to the bottom of the profiled slabs will increase the carrying capacity at bending. Thus, with reference to the articles placing of cold drawn steel rods, one in each profile, having a diameter of 5 mm, ultimate stress 1850 N/mm^2, will increase the carrying capacity of the articles with about 75%.

2. **Preferred articles with very strong composite materials - e.g. a compressive strength of at least 300 MPa.** Utilization of very strong tensile reinforcement as discussed above makes also demands on the pressure zones of the components. With unchanged geometry (8 mm thin layer of cement composite) the maximum compressive loadings (stresses) will amount to about 275-310 MPa when rupture of tension occurs. Securing against rupture occuring in the compressive zone (rupture at yielding by tension is usually preferred) can be effected by increasing the thickness (e.g. 10-12 mm instead of 8 mm) and/or by using special compressive reinforcement. A particular preferred aspect of the invention is use of particular strong composite materials, e.g. having compressive strength of at least 300 MPa. With reference to the above example, this makes it possible to maintain very thin articles (8 mm).

CONCEPTIONS - DEFINITIONS - EXPLANATIONS.

In this specification a number of conceptions occur which are used to characterize the invention. The most important ones will be defined/explained and motivated in the following.

Intimate contact. This term is used to characterize the contact between the composite materials and the profile sheets. With intimate contact is meant substantially complete atomic contact all over the contact surface as with moulding together, fusing together, gluing together and not as with e.g. bolting together or other mechanical joints. Intimate contact between the specific particle-based materials and the profiled sheets is further elaborated in the patent specification.

Compressive strength. The strength of the composite materials is characterized by claim to the compressive strength with reference to the strength measured by crushing a cylindrical article having a height/diameter ratio of 2 mm and diameter 100 mm, height 200 mm. The strength of the composite materials can be determined on special articles prepared of the composite material. The strength of the composite material as it is found in the hybrid articles (together with the profiled sheets) can also be determined by measuring on specimens sawn/bored out or by direct mechanial compressive loadings on the composite material as it is found together with the profiled sheets. By comparison/evaluation of the various determinations of compressive strength it is necessary to establish/prove the relationship to the compressive strength determined with the above cylinder specimens. That requirement to strength is related to compressive strength is due to a) the fact that in bending and compression the behaviour at rupture of the composite articles (provided effective co-operation with the profiled sheets) to a high degree is determined by the strength of the materials at compression, b) the compressive strength is often an acceptable property acting as a substitute for other strength characteristics - tension, shear - and c) the compressive strength is relatively simple to determine.

Modulus of elasticity. The rigidity of the composite materials is characterized by the modulus of elasticity referring to the inclination of the stress/strain curve at minor

loadings. The modulus of elasticity can be determined on particular specimens of the composite material, e.g. cylinders as mentioned in the paragraph concerning compressive strength. The modulus of elasticity of the composite materials can also be determined from measurements on the hybrid articles - i.e. with the composite materials in intimate contact with the sheet elements.

Such determinations can e.g. be performed from determinations of interdependent values of force and deformation of loaded articles or from determination of the resonant frequency of articles under free oscillations. The determinations are then performed on basis of the theory of elasticity applied on the composite article. The determinations presupposes that the behaviour of the profile sheets is known satisfactorily.

Energy of rupture. The rupture-toughness of the composite materials is characterized by the energy of rupture G - related to the behaviour at tension. The energy of rupture is defined as the work required to form a new crack of unit area (unit $J/m^2 = N/m$ or $J/mm^2 = N/mm$). The energy of rupture of the composite materials can be determined on particular specimens of the composite material - e.g. beams provided with a cut notch tested at bending, or a tensile specimen provided with notch and tested at tension. The energy of rupture of the composite materials can also be determined from measurements on the hybrid articles based on cut out specimens provided with cut notch.

The reasons for using the energy of rupture in relation to tension for characterizing the rupture-toughness of the composite materials are a) that the behaviour at tension is fundamental for rigid particle-based composite materials at rupture and crack formation; thus, rupture at shear occurs e.g. essentially through failure at tension, b) that the energy of rupture related to tension is a reasonable well defined quantity for rigid, particle-based composite materials, and c) that the energy of rupture related to tension is easy to determine by experiments.

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Placed external (or outside). The invention concerns articles with composite materials in intimate contact with profiled sheets placed preferably entirely or essentially external in relation to the bodies formed of the composite materials.

The formulation with preferred external placement is motivated in a discrimination between a) preferred articles according to the invention in which the profiled sheets act effectively through their placement in the outer side (closed to the outer side) of the bodies which they form together with the composite materials, and b) articles of composite materials according to the invention but with more centrally embedded sheets.

Thus, the sheet element in example 1 with profiled steel sheets combined with composite materials, placed on the outside of the body formed of the composite materials is typically preferred according to the invention. In similar manner articles according to the invention are obtained as pipes and containers builded up as curved embodiments of sheet articles according to the invention, e.g. as those shown in example 1, both when the composite material constitutes the inner shell and the profile sheet the outer shell, and conversely when the profile sheets are placed internal and the composite shell external. In no cases the profile sheets are completely or partly embedded.

It is differently with articles having a "block" of composite material, e.g. a foundation in which the one end of a profile sheet is totally embedded. Such article will only be preferred within the invention on condition that the article to a reasonable degree makes use of the characteristic mode of action according to the invention, e.g. due to very effective anchoring through the combination of the specific composite materials and the profiled sheets.

There is a large category of composite articles according to the invention which mere geometrically can be described by the fact that the profile sheets are completely or partly embraced by the composite material.

By way of example it may be mentioned that a limitation for a security box the bearing structure of which is a profiled steel sheet in intimate contact with a strong composite material on the one side thereof will completely satisfy the requirements to: "preferred according to the invention". This construction is designed for securing against high mechanical stresses. However, the limitation (door/wall/bottom or cealing) will typically also have to fulfil a number of other functions which can be provided for with materials placed additionally on the metal surfaces of the hybrid article, i.e. on the outside of the profile sheets. By way of example it may be fire protection, securing against local attack (e.g. with drills, chisels etc.), hidden by the construction, aesthetical consideration ect.

Often this will be established with other materials leaving the hybrid construction of the invention as described above as a clearly identifiable preferred article of the invention. However, for practical reasons the same type of composite material will often be used for attending to the non-primary constructive functions as the materials chosen for the bearing hybrid constructions; frequently such constructions are prepared in one moulding by means of which the profiled sheet becomes quite or partly embedded/enveloped in the composite material.

Such articles are of course just as preferred as corresponding articles with other materials for the not primary bearing functions and often even more preferred.

Study/demonstration of the shear capacity of the composite articles of the invention with profiled steel sheets but with moderate profiling and without any extra measures for securing against shear failure.

The construction of the composite slab is shown in Fig. 13. The composition and the properties of the components are shown in the paragraph "Materials". Fig. 13 shows a section in the composite slab. The length of the slab is 600 mm. 1 Is the composite material, 2 is the profiled steel sheet, 3 is a transverse reinforcement, viz. 6 mm diameter cam steel placed each 50 mm, and 4 is a longitudinal top reinforcement, viz. 3 pieces of cam steel, diameter 10 mm. The steel reinforcements are fixed so that they

did not loosen at vibration. The transverse bars are tack welded to the sheet at the ends 5 and the longitudinal bars are tack welded to the transverse reinforcement at the edge 6.

The composite slabs were subjected to transverse loadings in the disposition shown in Fig. 14.

Fig. 14 shows the test disposition of the composite slab 1 having the outside dimensions 600 x 230 x 40 mm, placed on the supports 2 and influenced of the vertical line loadings 3. The forces on each support and on each loading line are P/2, where P is the total force. The disposition is symmetric. The distance between the supports is: 500 mm; the distance between the support and the closest point of force attack is: 150 mm. During the experiment the free longitudinal edges 4 were observed through a magnifying glass.

During the experiment the slabs were subjected to varying loadings and unloadings at different loading levels varying from 0-25 kN to 7-91 kN.

Corresponding values of strains, deformations and applied force were recorded during the experiment. Besides, visual observations (through magnifying glass) were made of the two free edges of the slab.

MATERIALS.

The matrix, "the concrete", was prepared of materials from the firm Densit A/S. The composition is shown in scheme 1. The properties of the hardened matrix material is shown in scheme 2.

The profile sheet is of steel of the quality Fe510 B (according to EU 25-72 standards) often designated St. 52-3.
Sheet thickness: 2 mm
Tensile strength: 580 N/mm^2.

Yield point: 430 N/mm^2.

Measurement on sheets from the same supply as those used in the example. The sheet was sand blast 3 days before moulding.

Longitudinal at the top side: cam steel of 10 mm diameter, KS 520. Transversal: diameter 6 mm, KS 520.

Inducast 6000	26.33 kg
Ro - Bauxite 2 x 4 mm	8.47 kg
Steel fibres 0.15 x 6 mm	3.50 kg
Water	2.68 kg

Scheme 1. The composition of the "matrix" also called "the concrete", Inducast, is a fine sand concrete with Al_2O_3 rich sand and a binder based on cement, micro silica and dispersant (in dry powder form).

PREPARATION.

Specific weight (ρ)	2950 kg/m^3
Sound velocity (v)	5705 m/sec.
Dynamic E-modulus (Edyn)	96.0 GPa
Tensile strength (MPa)	225-260 (estimated)
Energy of rupture (Nm)	10,000 - 15,000

Scheme 2. The properties of hardened matrix material was measured on speciments prepared of the same mixture as used for the composite slabs and stored like these. The values for the compressive strength and the energy of rupture are estimated. The dynamic modulus of elasticity is calculated from measurements of the specific weight and the sound velocity: $E\ dyn = \rho \times v^2$

The matrix material was prepared in a forced mixing machine.

1. Mixing of the dry powder (except the steel fibres) about 1 min.
2. Addition of water and mixing about 5 min.
3. Addition of steel fibres and further mixing about 5 min.

Then the slab is moulded, placed horizontally on a vibration table subjected to vibration of frequency: 50 HZ amplitude. The slab is covered with plastic on the top side and stored about 24 hours at 20°C. Then it was wrapped in a wet cloth and tightly fitting plastic and stored about 4 days and nights at 70°C.

Cocurrently 3 test cylinders of the material (diameter 45 mm, height 90 mm) were prepared following substantially the same procedure as that for the slab.

Selected results are shown in scheme 3. Here is shown the interdependent values of measured quantities: applied force and strain in the middle section (see Fig. 14). Besides, the calculated values of stresses are indicated.

Applied force (kN)	Strains ( ) concrete	Strains ( ) profile steel	Stresses (Mpa) "concrete" compression	Stresses (Mpa) Steel tension	Stresses (Mpa) between concrete and steel displacement
25	330	403	32	63	abt. 1.4
36	500	711	48	149	abt 2.0
61	951	1334	91	280	abt. 3.4
91	1325	2297	127	440*	abt. 5.0

* start of yielding.

Scheme 3. Interdependent values of applied force and strains at top and at bottom, respectively, in the profile steel (at the center of the sheet) and estimated compressive and tensile, respectively, stresses in concrete and steel. Besides, the mean shear stresses acting in the longitudinal direction between the applied force and the support is shown.

Up to and including an applied loading of 61 kN corresponding to maximum stresses in "concrete" and steel of 91 and 280 MPa (respectively) and mean shear stresses between the steel and the concrete of about 3.4 MPa, no cracks were observed in the concrete nor any sign of separation between the profile steel and the concrete.

During 5 loading cycles up to 91 kN only a single small crack was observed in the "concrete" and separation of a part of the middle section between the concrete and the profile steel. After onloading and further loading to slightly above 91 kN rupture occured in the form of shear between the profile sheet and the concrete as shown in Fig. 15.

Fig. 15 shows in the form of a sketch a segment of the composite article between the support 3 and the line of attack 4 after shear failure (and suceeding bending failure between the lines of attack). At shear failure the "concrete part" 1 is pushed outward relative to the profile sheet.

EVALUATION.

The composite article was designed for experimental purposes with a clear view of elucidating the shear capacity of articles according to the invention, but

1. with a very moderate profiling, and
2. quite without particular measures for securing against shear failure, and
3. with large sheet thickness relative to the profile height, and
4. relative high steel strength.

Comparison between the profile sheet of the test specimen of this example and the profile sheet in example 1 is shown in scheme 4.

	Profile sheet for test composite Ex. 2	Profile sheet for composite article Ex. 1

slope angle	54°	84°
Opening relative to a/h height	2.35	0.91
height relative to thickness (h/t)	8	22

Scheme 4. Comparison between the profile sheet in the experiment with profile sheets of moderate profiling and the profile sheet used in the construction, cf. example 1. As to explanation reference is made to Fig. 16.

Fig. 16 shows a section of profiled steel sheets used in this example 2 and in the composite article described in example 1, respectively. Indications of the geometry sizes, cf. scheme 4, are marked in the Figures.

Up to shear failure the composite slab showed high inner cohesion without crack formation but with high rigidity, e.g. corresponding to above 70% higher rigidity than for a corresponding article of massive aluminium.

Shear failure occured at a mean shear stress of between that for profile steel and that for "concrete" about 5 MPa. The value is calculated on the basis of the total surface area between force action and support including the two halves outer profile sections where the shear resistance is substantially lower due to lack of squeeze action. Without including the contribution from the outer sections, which are not representative for the slab construction, the force at rupture corresponds to a mean stress of about 7 MPa.

These values are high and surprising to the man skilled in the art viewed in the light of known technology. Thus, it is stated in "Steel Designers Manual": If design were to be carried out on elastic principles, permissible bond strengths between deck profiles and concrete would be of the order of 0.05 N/mm^2 (0.05 MPa) for plain profiles rising to 0.2 N/mm^2 (0.05 MPa) for some idented profiles.

The profile in the present example 2 is clearly of the former type - "plain profile" - without any form for particular shear arrangements. This means that the shear stress in example 2 of about 5 MPa is of the order 100 times higher than what would usually be allowed according to the known technology.

The example clearly demonstrates the concept behind the present invention based on a combination of profile sheet plus matrix of high strength, high rigidity and high rupture-toughness, viz. achievement of a very high shear resistance, even with the here used steel sheet of very moderate profiling.

It should be stressed that the aim with the test specimen just was to study boundery cases with composite articles according to the invention having steel sheets of very moderate profiling. That the article showed high shear resistance does not indicate that it is a preferred article of the invention. On the contrary, the present invention states more preferred profilings, e.g. with an angle between the web and the flange preferred high, e.g. higher than 60°, preferably higher than 70°, more preferably higher than 80°, most preferably higher than 85°.

Another aspect of the invention is a composite article according to the invention wherein protection against shear failure and other failure between the profile sheet and the composite material is increased by particular anchoring arrangements. This aspect with particular anchoring arrangements is universal, covering both composite articles of the invention with very moderate profiled sheets and articles with very strongly profiled sheets.

COMPARISON OF PLATE ELEMENTS HAVING THE SAME OUTER GEOMETRY BUT OF MONOLITIC MATERIAL.

Below (scheme 5) the calculated behaviour of analogue elastic plate articles of monolitic material is shown. The indicated values of the modulus of elasticity are determined as the values which the monolitic plate element should be ascribed in order

that the article is deformed exactly like the composite slab (referring to the behaviour of the composite slab after the first loading/unloading cyclus).

The shear stresses refer to the stresses in a horizontal plane at top of the ribs. Reference is made to the mean values of the shear stresses across the whole area extending from the force transmission to the support (150 mm). The values are shown in scheme 5.

Loading (kN)	Stress (N/mm^2) bottom (tension)	top (compression)	horizontal section (shear)	Modulus of elasticity of analogue material (N/mm^2)
31.0	66	47	3.1	124 000
36.0	76	55	3.6	108 000
60.2	127	92	6.0	96 000
90.8	192	139	9.1	91 000

Scheme 5. The behaviour of an analogue monolitic article of material which show a linear elastic behaviour. In the last column the values of the modulus of elasticity are shown, which should be ascribed the analogue monolitic material in order to obtain exactly the same deformation as that for the composite article of the example.

Comparison with analogue articles of aluminium having substantially the same weight (about 90%) is interesting. Up to a stress level of 60 N/mm^2 the rigidity (modulus of elasticity) is quite 77% higher than that for aluminium and even with stresses of quite up to 192 N/mm^2 the composite article is substantially more rigid than aluminium. The E-modulus is here about 30% higher than that for aluminium at small loadings.

In the comparison with aluminium values for E-modulus of 70,000 N/mm^2 are used, which are typical values for aluminium at minor loadings/low stress levels.

EXAMPLE 3.
Experiments with thin composite slabs according to the invention subjected to repeated impact actions with sledgehammer.

A 40 mm composite slab according to the invention was subjected to repeated impact actions according to international rules for testing approvement of safe boxes.

The slab was composed of a profiled, 2 mm thick steel sheet in contact with strong, tough, particle-based composite material - total thickness 40 mm. The construction of the composite slab was quite identical with the composite slab shown in example 2, vide i.a. Fig. 13, except that in the slab of the present example there are two longitudinal steel reinforcements for each profil section compared to one in the slab in example 2 and that the instant slab is a little larger, external dimensions of 600 x 540 mm compared to 600 x 240 mm for the slab in example 2.

A sketch of the profile section is shown in Fig. 17. Fig. 17 shows a segment of a cross section of the composite slab used in this example. 1 Is the composite material, 2 is the profiled steel sheet, the measures of which are as for the slab of example 2 shown in Fig. 13. 3 Is the transverse reinforcement of 6 mm in diameter cam steel per 50 mm. 4 Is the longitudinal top reinforcement of 8 mm in diameter cam steel, and 5 is the longitudinal bottom reinforcement of 12 mm in diameter cam steel. The main dimensions of the slab are: length 600 mm, width 540 mm, thickness 40 mm and 24 mm (respectively at the profile top and the profile bottom). The composite material, the preparation and the hardening were as for the slab in example 2.

The slab was subjected to the standard test for safe boxes/panels for safe boxes to simulate attack with sledgehammer and blowpipe.

Test of this type is used to test box-panels for money boxes. Those with which the comparison is made are composed of strong cement-based composite material of the same type and substantially the same quality as that used in this example.

The conventional panels, which were selected for comparison purposes, have the same thickness as the maximum thickness of the present profile slab (40 mm) but have 4 times more sheet steel than that according to the example. Two slabs has each a thickness of typically 3-5 mm compared to a thickness of 2 mm of the sheet in the present example. (If regard is paid to the profiling of the sheet according to the invention corresponds this to about 2.6 mm^3 steel sheet per mm^2). If the reinforcement bars, which often also are found in conventional slabs, are included there is no essential amendment of the fact that the total steel reinforcement still only constitutes about 25-50% of what is conventionally used.

The conventional slabs in the comparison are, as mentioned, 40 mm thick. The slab thickness in the example is in average only 32 mm (with 40 mm and 24 mm, respectively, in the profile top and profile bottom), there is only 80% in average of the slabs with which they are compared.

During the test the slab is supported along the edges. The slab is placed about 1.5 m vertically above the floor in a position well suited for attack with the sledgehammer. A marked out area of the slab (120 x 120 mm) on the concrete side was subjected to a number of powerful stresses/impacts with a 3 kg heavy sledgehammer. The test was performed by an experienced, strong testperson. Each impact was conducted with what the person described as "with power".

The head of the sledgehammer (of steel) had a mass of 3 kg. The length of the handle was about 75 cm.

By such test destructions occur in the form of one or more of the following mechanisms: 1) local crushing, 2) through-punching (press out of a truncated cone-shaped body), and 3) bending of the composite slab.

The measures taken in accordance with the invention by using profiled steel sheets instead of plane sheets as in conventional panels have primarily effect against the lat-

ter two mechanisms - resistance against through-punching and against bending - but no direct effect against local crushing.

If on the other hand beginning through-punching or slab bending occur which led to high concentrated stresses in the zone of attack, e.g. in the form of high compression in the surface in the plane of the slab, the resistance against local crushing may be reduced substantially.

The article resisted 80 hammer impact plus various blowpipe activities in order to remove the steel reinforcements before the profile sheet at the bottom was reached and could be cut away.

With conventional panels having the composite material placed in a box with plane steel sheets both in front and at bag, a section of the front sheet (120 x 120 mm) is initially removed with blow-pipe cutting and hand tools. Then the uncovered area is attacked with the sledgehammer until the rear steel sheet can be removed with blow-pipe cutting.

40 mm thick conventional panels resist typically 10-30 hammer impacts as for articles without the reinforcement bars and 1.5 to 2 times more for articles further provided with reinforcement bars, thus, 20 to max. 60 impacts.

Thus, there is an essential improvement with the invention which required as much as 80 impacts in spite of an essentially thinner steel sheet and a thinner construction.

During the initial phase (corresponding to 30-45 impacts) the local crushing was small corresponding entirely to the initial behaviour of thick articles of the same material where resistance against crushing dominates.

At this point the hollow has reached a depth of 5-10 mm.

Then more crushing occured and in the last phase also high local bending outwards of the profile sheet, which in the zone of attack now was essentially not protected by the matrix material. The behaviour during the initial phase illustrates the good capability of the composite article to absorb bending and shear without failure between the steel sheet and the concrete.

Beyond the fact that the resistance against crushing was as in thick articles of the same material (indicating good resistance against through-punching and bending) no cracks were observed on the front side of the slab outside the zone of attack. This is also an indication that no form of failure occured due to through-punching or shear and again that there was good contact between the steel sheet and the concrete.

Even after break through the front side of the slab was substantially crack-free apart from a few longitudinal fissures.

Compared with conventional panels, 40 mm thick and with 2-5 mm steel sheets on each side and of the same sort of composite material, the behaviour is very interesting and surprising to the man skilled in the art.

1. The substantially thinner and more poor in steel composite slab of the invention resisted substantially more hammer impacts than the reference panels - 80 against 20-60.

2. On the front side of conventional panels subjected to hammer impacts there was observed (after removal of the steel sheet) comprehensive crack spreading from the zone of attack all over the quite slab. This was not the case with the panel slab of the present invention.

3. This indicates a surprising and unique resistance against shear failure between the concrete and the steel sheets in the panel of the invention - reinforced by that

4. In the panel of the invention there is only one steel sheet compared with two in the conventional slabs, and that

5. The resistance against bending failure and through-punching according to prior art otherwise should be expected to be even much inferior for the essentially thinner panel of the invention, e.g. with a very modest bending resistance transverse to the ribs.

It should be clarly emphasised that the purpose with the experiment was not to test a finished construction but to obtain information about the resistance of the composite article against repeated impact stresses in an embodiment having some relevance for the safebox-industry.

By was of example, the preferred safety panels according to the invention do not contain only one profile sheet, but typically two or more profiled sheets.

CLAIMS

1. A hybrid slab for construction of objects for the absorption of static loadings, such as on wall, floor, and ceiling construction, or for the absorption of dynamic loadings, such as on safety boxes and surfaces on trafic lanes in airports and public roads, said slab being composed of a particle-based composite material in intimate contact with a profiled sheet element, said composite material comprises at least a base material in the form of particles of the base material and a binder which maintains the particles of the base material in position relative to each other, and the sheet element comprises a material which is capable of being extended in planes as for the profiled sheet element, characterized in that a volume of the composite material constitutes at least 50% of the volume of the hybrid slab.

2. A hybrid slab according to claim 1, characterized in that the volume of the composite material constitutes 55% of the volume of the hybrid slab, preferably 60% of the volume of the hybrid slab, more preferably 65% of the volume of the hybrid slab, most preferably 70% of the volume of the hybrid slab.

3. A hybrid slab according to claims 1 or 2, characterized in that the composite material comprises fibres and the volume of the fibres constitute 0.1 - 1% of the volume of the composite material, preferably 1 - 2% of the volume of the composite material, more preferably 2-5% of the volume of the composite material, most preferably 10-20% of the volume of the composite material.

4. A hybrid slab according to any of the preceding claims, characterized in that the composite material comprises particles for increasing the hardness of the composite material, preferably particles of rocks such as quartz, diabase and granite, more preferably particles of crystals such as alumina, silicon carbide and silicon nitride, most preferably particles of metals such as steel and alloys of steel, and that the particles for increasing the hardness constitute at least 30% of the volume of the composite material, preferably at least 40% of the volume of the composite material, more

preferably 50% of the volume, yet more preferably 60% of the volume of the composite material, most preferably 65% of the volume of the composite material.

5. A hybrid slab according to any of the preceding claims, characterized in that the composite material comprises elements for reinforcement of the composite material and that the elements comprise a number of bars, a number of threads, and number of networks and a number of fibres.

6. A hybrid slab according to any of the preceding claims, characterized in that the binder comprises cement, that the binder contains microfine particles such as micro silica, that the volume of the microfine particles constitutes at most 40% of the volume of the binder, more preferably 5-25% of the volume of the binder, that the binder contains fine particles such as cement, preferably Portland cement, alternatively Aluminate cement, and that the volume of the microfine particles and the fines together constitute at least 50% of the volume of the binder, preferably at least 55% of the volume of the binder, more preferably at least 60% of the volume of the binder, yet more preferably at least 65% of the volume of the binder, most preferably at least 70% of the volume of the binder.

7. A hybrid slab according to any of the preceding claims 1-6, characterized in that the sheet element is made of metal, and that the metal is selected from the group consisting of steel, copper, nickel, titanium, aluminium and alloys thereof.

8. A hybrid slab according to any of the preceding claims 1-6, characterized in that the sheet element is made of a non-metal and that the non-metal is selected from the group consisting of ceramics and plastics.

9. A hybrid slab according to any of the preceding claims, characterized in that the profile of the sheet element as a trapezoidal cross section, that the trapezoidal cross section has sides which extend in an angle relative to the plane of the sheet of 10°, preferably 20°, more preferably 30°, yet more preferably 45°, most preferably 60°.

10. A process for the production of a hybrid slab according to any of the preceding claims, c h a r a c t e r i z e d in that the composite material is produced by using the sheet element as form, alternatively that the sheet element is produced by using the composite material as form.

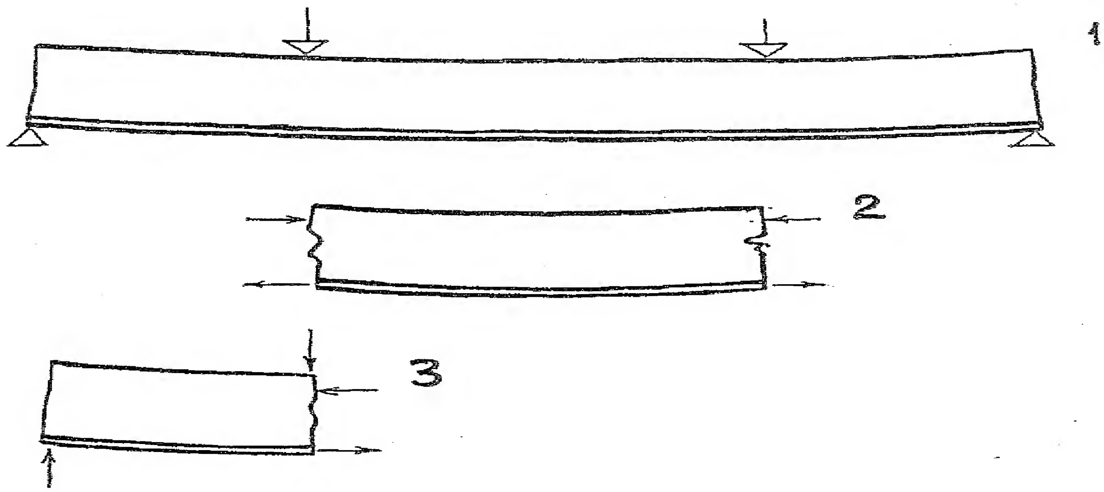

FIG. 1

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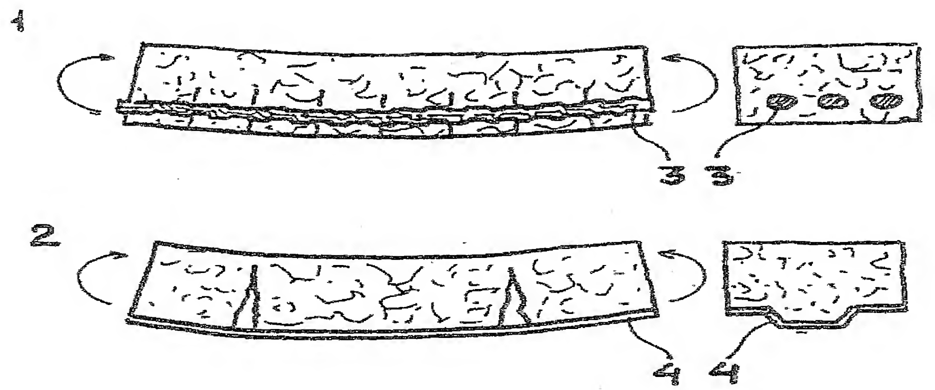


FIG. 2

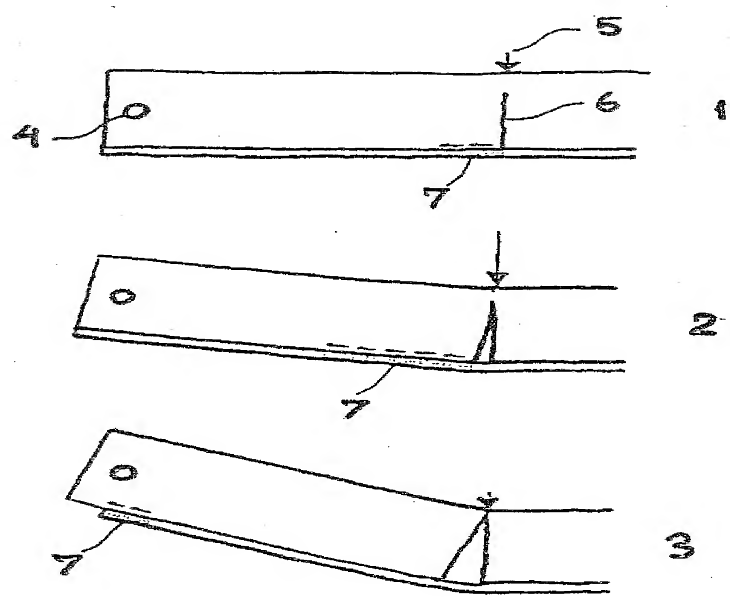


FIG. 3

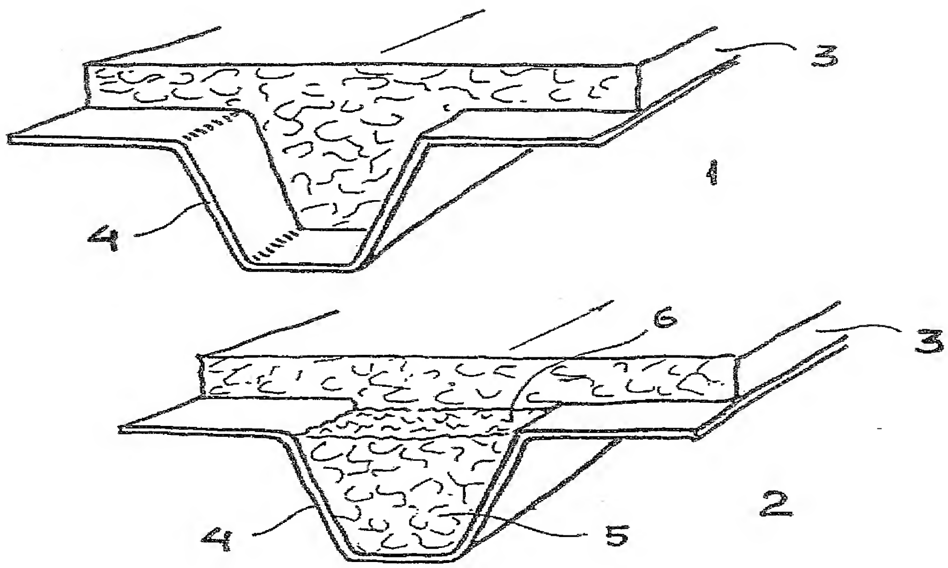


FIG. 4

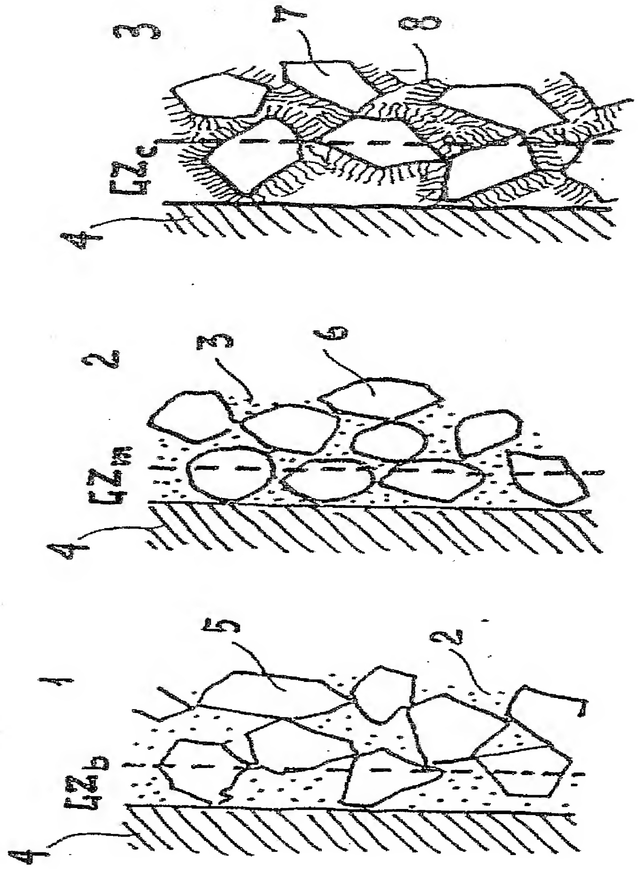


FIG. 5

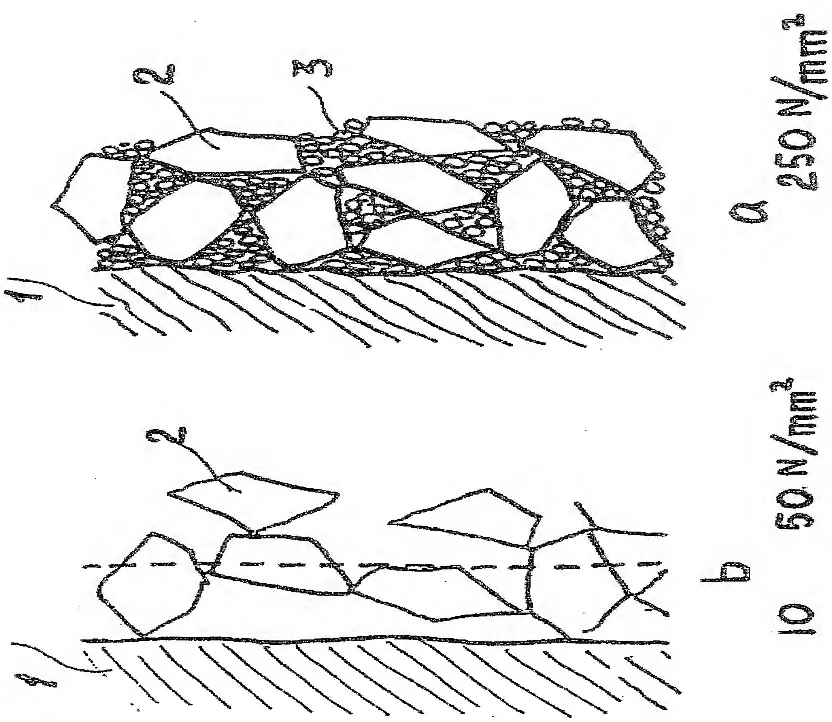


FIG. 6

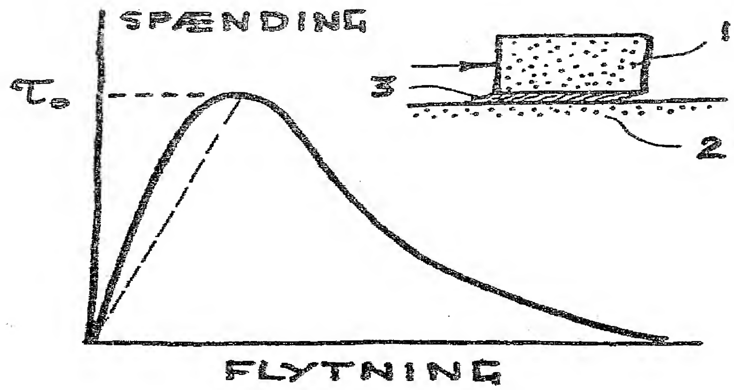
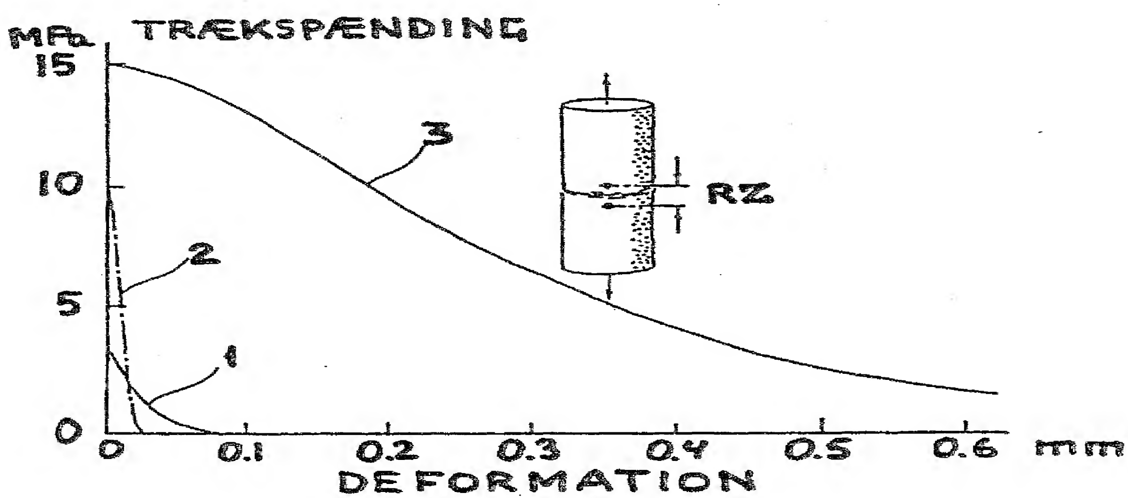

SPÆNDING
τ_o
1
3
2
FLYTNING

FIG. 7


MPa
TRÆKSPÆNDING
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10
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RZ
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0.6
mm
DEFORMATION

FIG. 8

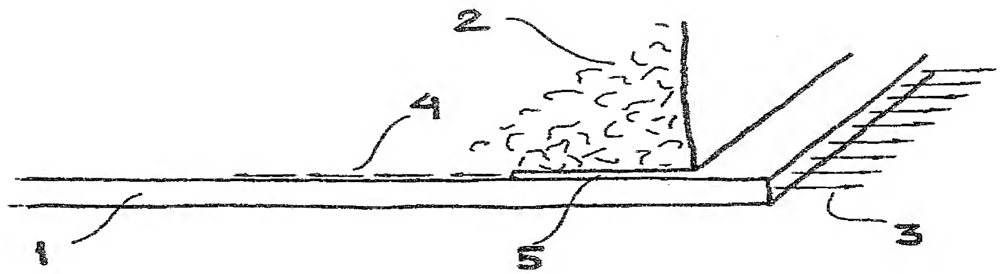

FIG. 9

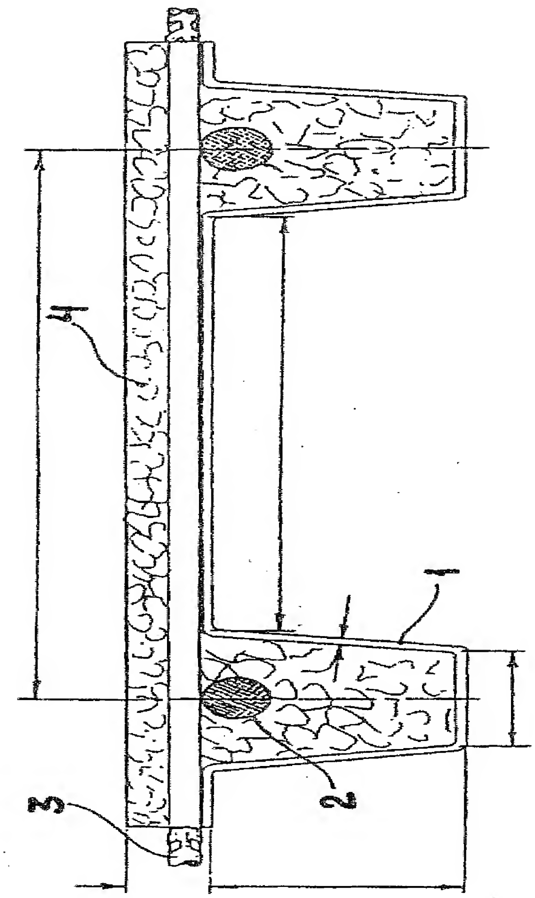

FIG. 10

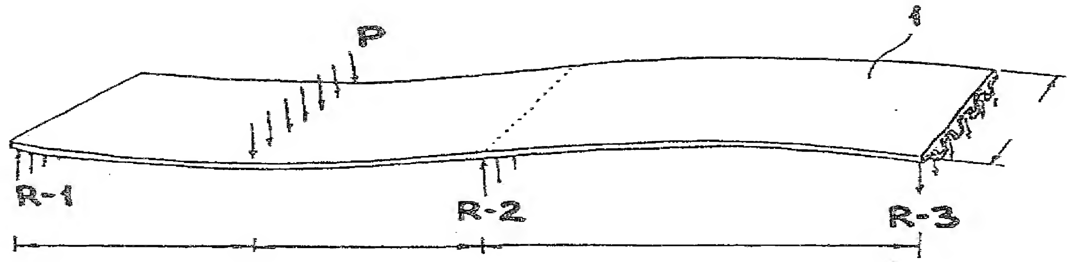

FIG. 11

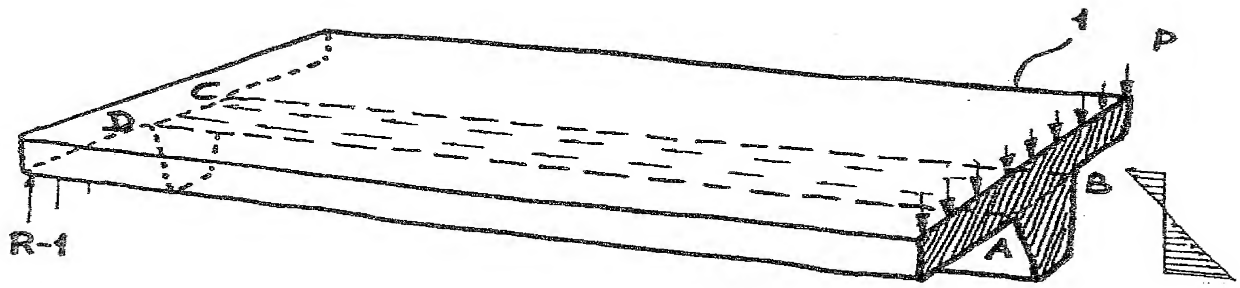

FIG. 12

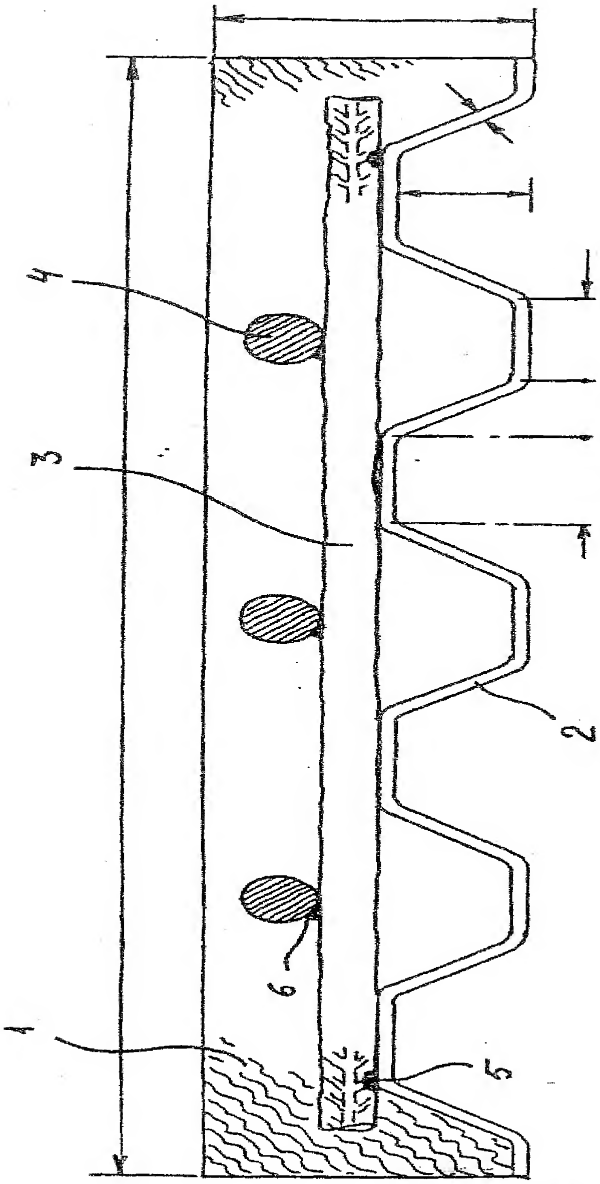

FIG. 13

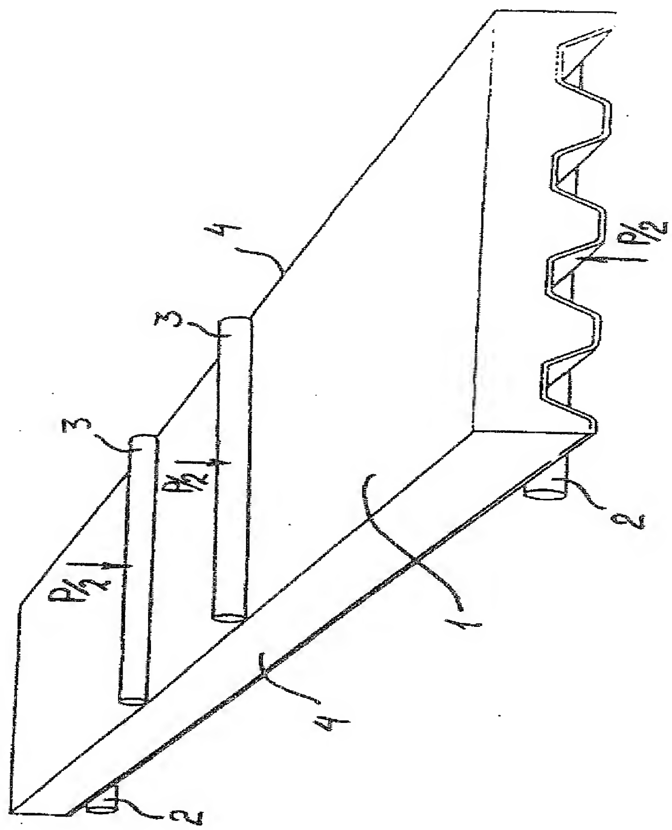

FIG. 4

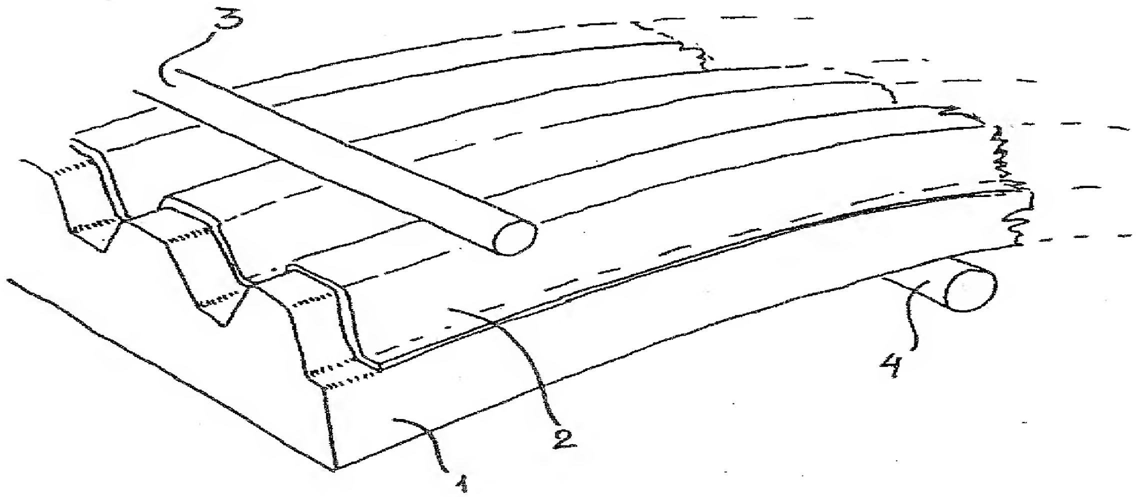

FIG. 15

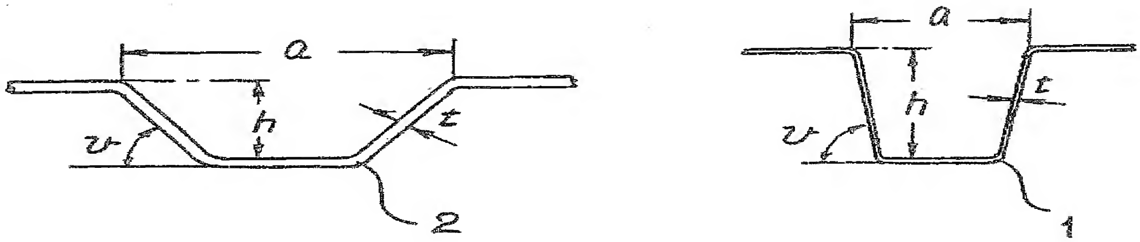

FIG. 16

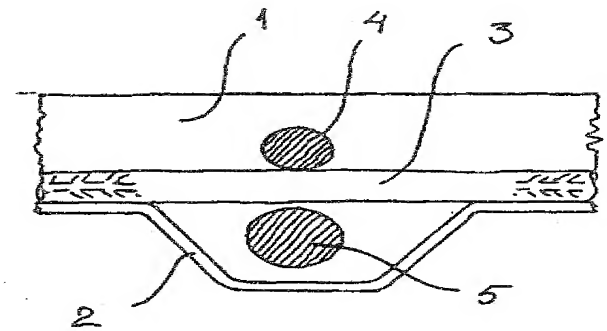

FIG. 17

BNSDOCID: <WO 9733054A1 I >

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 97/00097

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: E04C 2/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: E04B, E04C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 1073540 A (P.M. STEWART), 16 Sept 1913 (16.09.13), page 1, line 64 - line 91, figures 1-3	1,10
Y	WO 8603245 A1 (PERMANENT FORMWORK LIMITED), 5 June 1986 (05.06.86), figure 4, abstract	1,10
A	DE 1800858 A (SIEGENER AKTIENGESELLSCHAFT GEISWEID, EISENKONSTRUKTION, BRÜCKENBAU), 27 May 1970 (27.05.70), figure 1, claim 1	1-10
A	DE 2135128 A (STEFFENS & NÖLLE GMBH), 1 February 1973 (01.02.73), figure 1, claims 1-9	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" erlier document but published on or after the international filing date
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"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 June 1997	16 -06- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Vilho Juvonen Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Information on patent family members

20/05/97

International application No.
PCT/DK 97/00097

Patent document cited in search report			Publication date	Patent family member(s)			Publication date
US	1073540	A	16/09/13	NONE			
WO	8603245	A1	05/06/86	AU	5044885	A	05/06/86
				EP	0183526	A	04/06/86
				GB	2167466	A	29/05/86
DE	1800858	A	27/05/70	NL	6917041	A	27/05/70
DE	2135128	A	01/02/73	NONE			